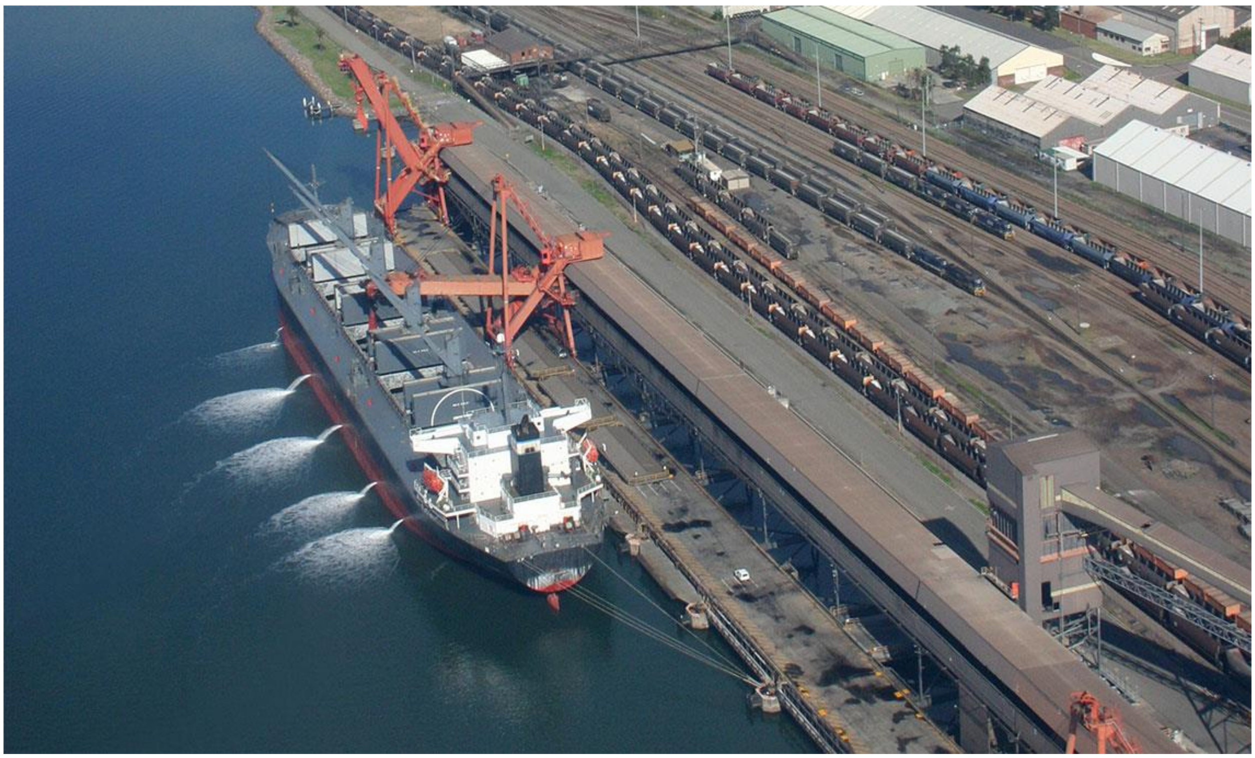
MASTER OF SCIENCE DIPLOMA IN

SUSTAINABILITY AND QUALITY IN MARINE INDUSTRY



M.Sc. Thesis on "Ballast Water Treatment Methods – Systems"

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ABSTRACT

The present thesis focuses on ballast treatment technologies and how these can be assessed by the buyer in order to select the most appropriate Ballast Water Treatment System (BWTS) for a Bulk Carrier Dry cargo ship. The study begins with the First Chapter, which aims to present an introduction to the concept of biodiversity and to the reason that the need for immediate action to protect it effectively is imperative. The invasion of alien organisms into ecosystems where they are not their natural habitat is the main problem that poses a major threat to biodiversity and is presented in detail in this chapter with some examples of harmful organisms to make the problem more approachable to the reader. In conclusion, it becomes clear why ballast processing technologies have been developed over the past few years. Subsequently, Chapter Two extends to the analysis of the subject with regard to the regulatory framework surrounding ballast management and its evolution. In chapter Three, initially, it focuses on the factors which a ballast treatment system can be properly fitted and operational for the ship. The following is a breakdown of these methods by category based on how ballast is being processed. Next, it is being analyzed the basic processing methods of all three categories in terms of the advantages and disadvantages of each method. In conclusion, in the Fourth chapter an introduction to the method of Multicriteria Analysis and the AHP - TOPSIS combinational model will be applied to the case study that follows. The data presented is real and based on a specific business profile of the shipping company from which they were taken from. It is therefore a comparison of four ballast treatment systems to find the system that is most suitable for the eight-year-old Supramax-Bulk Carrier (DWT: 56.735) ship of the company, after the process is completed. Keywords: Ballast Water Management System (BWMS), biodiversity, Multicriteria Analysis, AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), Owner shipping company, Bulk Carrier.

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1. INVASIVE SPIECES IN MARINE ENVIRONMENT

1.1. What is biodiversity and what does it offer us

Biodiversity is the number of organisms that live on Earth and participate in almost all processes that occur, from climate regulation and soil retention until the sustainability of agriculture and fisheries as well They are also the basis for many industrial products, as well as for drug production (National Geographic). In other words, biodiversity is diversity of life, in all its manifestations. If taken into account in the most its wider dimension biodiversity incorporates all types, level sand combinations of differentiation of living beings in nature. Maybe should be added to the above and the diversity of the landscape in the sense that the landscape although not a "living" part of an ecosystem, nevertheless, participants essentially in shaping the composition of the species of flora and fauna that live in an area and more generally, composition and types ecosystems (or habitats) formed on each different appearance of landscape variety. Thus, in an area with intense geophysics relief and in which there are many alternations of landscape and abiotic elements (different reports on the horizon, the presence of a stationary or running water, various types of geological substrate, etc.), the "Hosting" respectively a large biodiversity of plant species, animals and species microecosystems (NEW EARTH CELL, 2012).

Biodiversity conservation values include:

• The social-economic relation with the benefits that result from biodiversity, in particular to eradicate global poverty.

• The pharmaceuticals with the multitude of biological substances on which almost all corresponding treatment methods are based.

• The aesthetics and culture that meet the deepest needs of man

• The ecological ones related to their survival and smooth operation more ecosystems which contribute to their conservation environmental conditions of the planet (Peppas, 2019).

1.2. Why protecting biodiversity is important?

The need for coordinated international action to protect biodiversity emerged from the scientifically substantiated finding of loss biodiversity worldwide and the international recognition of its value for Humanity. The Rio Conference in 1992 was its culmination global recognition of the need to conserve biodiversity, and international political recognition of the term "biodiversity". The purpose of the international Biodiversity Convention, signed in Rio in 1992, as defined in Article 1 thereof, is "the conservation of biological diversity, the sustainable use of its components and their fair and equal distribution benefits that will result from the use of genetic resources... ". Greece is a part of International Convention on Organic Diversity. In addition, in 2001, its Heads of State and Government The aim of the European Union (EU) was to "halt its loss biodiversity [in the EU] by 2010 ". In 2002, leaders of 130 states pledged to "Significantly reduce the rate of biodiversity loss [worldwide level] by 2010 ". Relevant polls show that EU citizens wholeheartedly embrace this concern for biodiversity (Bank of Greece, 2011). Biodiversity loss is a cause for concern, not only because of the particular inherent value, but also because biodiversity is an element of it on which competitiveness, growth and employment, as well as the improvement of living conditions (European Commission,2006). In addition, the loss of biodiversity leads to a degradation of services provided by ecosystems. Ecosystem services are defined as processes and functions provided by the natural environment that benefit it man. It is estimated that the oceans and especially the coastal zones contribute to it from 60% to the total economic value of the biosphere. Hence the problem of foreign bodies need immediate treatment in order to exist restoration of ecosystems but also of economic profit. Between services mentioned above include the production of food, fuel, fiber and medicinal substances, the regulation of water, air and climate. One of the main causes for biodiversity loss and ecosystem degradation is the introduction of organisms and the establishment in ecosystems outside their natural environment. These organizations are offen called foreigners. Consequently, ballast treatment technologies were also developed to remove foreign organisms contained in seawater entering the ship when stability adjustment is required (eg in case the ship does not carry cargo, it is considered necessary to ballast water intake so that it can be stable).

1.3. Bio-invaders

Many species of organisms have the ability to move on their own from place to place in place. Other organisms may be intentionally or unintentionally transferred to one area outside their current or past natural distribution. These species are called alien and can enter another ecosystem either as whole organism, either through eggs and seeds, or even a part of them (eg. a branch) that manages to survive and reproduce (Matej, 2015). When alien species cause problems in their new ecosystem they are called toxic bio-invaders. Internationally invasive species are taken as the second highest risk for biodiversity loss, after habitat destruction (WWF Hellas, 2011). Indicatively, in Greece from the total of 325 foreign plant species that we find50 are classified as invaders. The majority of them are found to be anthropogenic environments and around them such as crops, road networks, urban and generally residential areas. There are of course species that have acclimatized fully and are found in many natural habitats such as sour (Oxalis pes Caprae) , the conifer (Erigeron bonariensis) and the German (Solanum eleagnifolium) (WWF Hellas, 2011).

1.4. Ways of importing non-native organisms

1.4.1. Physical movement of items

Some organisms can be transmitted by their own means, for example, migrations between long distances usually performed by migratory birds, can lure together organisms that either cling to them or infect them. Typical example are the species of branch antennae that belong to their family crustaceans. This species is usually attached to the legs of birds and thus their transfer from one ecosystem to another can be explained (Matej, (2015). Of course, sea currents can contribute to the movement of organisms under rare and special conditions that will favor an organism to escape from the boundaries of the place where its reproduction is favored, perhaps due to the climatic conditions changes, such as the increased spread of sardines (where against times shows increased rates south of the North Sea and west Baltic as a result of the rare inflow of the Northeast Atlantic Ocean and the highest water temperature (Matej, (2015) .The result of this natural phenomenon in the biodiversity of the natives can be temporary and limited in scope as it is known as rare visitors or stray organisms. This, then, is physical movement of species between ecosystems is considered something completely natural and does not cause problems, on the contrary it is often taken as an advantage. On the other hand, human intervention in the transport of foreign organisms can cause irreversible negative effects (Matej, 2015).

1.4.2. Movement of items with human intervention

In contrast to the naturally occurring spread, the invaders are alien species can invade areas outside their natural distribution because of it human intervention (import, transit, conservation, breeding, cultivation, reproduction or deliberate release), and spread-install, threatening local biodiversity and especially the highly isolated geographical and evolutionary ecosystems, such as those of small islands (Dasarxeio, 2017) .Pursuant to Regulation (EU) no. 1143/2014 of the European Parliament and the Council for its comprehensive and coordinated response problem of invasive alien species at European level, h European Commission has compiled a List of Invasive Foreign Species of the Union Of interest. This Directory, published on 14 July 2016 in Official Journal of the European Union (Implementing Regulation (EU) No2016/1141 of the Commission), includes a list of 37 species of organisms (23 animals and 14plants). For the items of the Catalog it is not allowed: a) import in its territory Union, including transit under customs supervision; (b)conservation, even under restriction; (c) breeding, even under restriction; transport, from or within the Union, with the exception of the transfer of items to installations with a view to their elimination; (e) placing on the market; (f) use or(g) enabling reproduction or cultivation, even under restriction; h) release into the environment (Dasarxeio, 2017).

1.4.3. When did the problem occur?

Foreign organisms have been transported since man began to explore the world. In ancient times the ballast of ships consisted of a pile of stones, thus many organisms trapped between the stones or even in the ship's own cargo, they were transported to other ecosystems usually without human knowledge and any local authority control. Many of these movements of foreign organizations are not listed in detail in any list except a few and there is no clear picture of the species that existed in ecosystems for centuries before (Matej, 2015).

The rapid growth, which has taken place over time, of land maritime as well as air transport over the last 50 years contributes dramatically the spread of invading species that exploit it as smugglers import of food, propagating material, seeds, raw materials and agricultural products, along with any weeds, are carried in the ballast of ships, even the travelers' luggage (WWF Hellas, 2011).

1.5. Introduction of foreign organisms into the marine environment

There is particular concern worldwide about the phenomenon of foreign imports species in the marine environment. The main carriers of non - native organisms in marine environment are navigation, natural or man-made canals, aquaculture but also the 'escape' from aquariums and research institutes. It is estimated that most of the imports are due to inland navigation from the sea ballast of the ships (as mentioned above) and the deposition organisms such as shellfish on the reefs of ships and more generally on the exterior their surfaces. The sea ballast of ships contains many marine organizations. Once the ballast is released into the environment, these organisms enter the ecosystem, where they compete with those existing food organisms (Helmepa Sailors, xx). Studies show that shipping (ballast and ship reefs) is the main carrier transport of non-native species in the seas around the world (Kotrikla, 2017). More in particular, as far as the reefs of ships are concerned, they are being developed there as well are attached to marine microorganisms that result in their transport toother ecosystems, surface erosion and their hydrodynamic behavior. Nevertheless, the problem with microorganisms on the ship's reefs are treated using antifouling paints. These dyes release biocidal substances (eg. Tributyltin - TBT) which inhibits the growth of marine fauna and land fauna. TBT causes endocrine system disorders shellfish. This phenomenon is known as 'imposex' and means female organisms develop male characteristics due to the action of TBT in their hormonal system. This action occurs in gastropods even when the TBT concentrations in water are extremely small (Helmepa Sailors, xx).

The International Convention on the Control of Harmful Protection Systems Shipwreck (AFS Convention), which entered into force in September 2008, prohibits the use of organotin compounds in reef colors used on ships (Helmepa Sailors, xx) .In the Mediterranean, after ballast, aquaculture is the second most important alien transport agent. For example, fish used in fish farms for commercial reasons sometimes "escape" and spread in the marine environment (Lambrinidis, 2011). Natural or artificial sea channels are another means of importing foreigners. A typical example is the opening of the Suez Canal, the1869. The migration of marine organisms of the Red Sea through of the Suez Canal in the Mediterranean is called the Lessepsian Migration (the This name was given in honor of Ferdinand de Lesseps, architect and responsible for the Suez

Canal project). The marine organisms which cross the canal through the Red Sea ending in the Mediterranean, are called Lesbian immigrants (Marine Insight, 2017).

From this time, the movement of a large number of alien species from the Red was noticed Sea in the Mediterranean. An increased influx of thermophiles has now been observed organisms due to climate change and rising temperatures in surface waters of the Mediterranean and the Greek seas (Its Sailors Helmepa, xx). Alien species can invade other ecosystems and through research that man does and in his effort to restore ecosystems who seem to be 'sick' (Kotrikla, 2017) .The oceans most affected by marine invaders are the North Atlantic, North Pacific and East Indo-Pacific (Figure 1). In North Atlantic, for example, 240 alien species have been recorded, 57% of which are harmful or invasive species.

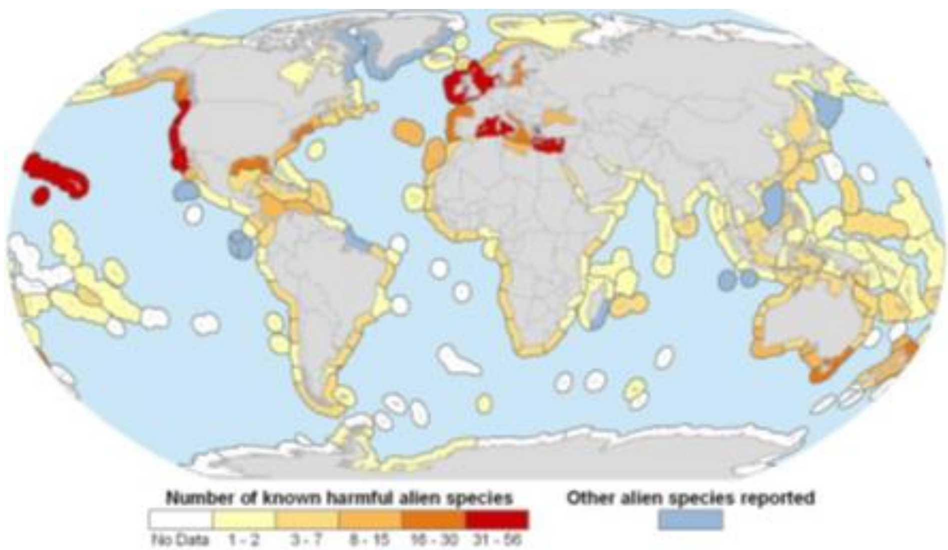

Figure 1 Indication map of areas affected by alien species (IMO Sea and Environment, 2018)

The above world map shows the number of harmful alien species depending on the coastal ecosystems. The darker shades of red show increase in the number of species with significant effects on local ecology. The blue indicates eco-regions with alien species designated as less harmful (Seos Project, eg).

Foreign organisms do not have any restrictions on surviving any place away from their natural environment as long as they are under the map propriate conditions. Marine invasive alien species cause loss of biodiversity leading to the extinction of indigenous species, and vαcan Significantly alter the structure and functions of the marine ecosystem and cause damage to economic activities (fishing, tourism, etc.) and in human health. This is especially the case when these species invade one ecosystem already considered vulnerable due to other pressures (Bank of Greece,2011). So, when they find themselves in these conditions and manage to survive, can become part of the ecosystem fauna posing extremely difficult of their elimination. This has the effect of degrading their quality ecosystems, and most importantly, the loss of the services they offer these ecosystems. An illustrative example of a disorder caused by a foreign organism is the tropical dinosaur *Citharistes* regius. The tropical dinosaur *Citharistesregius* was first mentioned in the Mediterranean off the Ionian Sea. Further, reports of toxic benthic *dinoacidogues* on the Mediterranean coast have been growing over the last decade. Specifically, the spread of species tropical genera, such as the genera *Gambierdiscus* and *Prorocentrum* in Greece is a biological indicator of climate change in the region. Specifically, the first reference of the species *Gambierdiscus* sp. in the Mediterranean came by sea area of Crete, in the year 2003. In 2009, the species was found in the Saronic Gulf, *Saladin*, extending its spread even further north (latitude ~ 38oN) in the Mediterranean basin. This benthic *dinofibrillator* produces toxins that are responsible for ciguatera, a form of food poisoning from which affects more than 50,000 people each year after consumption fish, mainly in peripheral areas (Bank of Greece, 2011).

1.6. Foreign organisms in ballast tanks

Shipping carries over 90% by weight of goods worldwide level and at the same time 3-5 billion are transferred. tons of ballast internationally per year (Lloyd's Register, 2015). The ballast is seawater along with its floating pumped to the ship in special tanks (ballast tanks) for the regulation of the conduct, sinking and stresses of the ship, especially when is unloaded (Matej, 2015).

According to expert estimates, 3000 - 4000 different species move every day worldwide by ships. More recent estimates show that the number of foreign species transported by ships amount to 7000 daily excluding microorganisms such as bacteria and pathogens (Matej, 2015). The organisms that are most likely to be transmitted through the ballast are found usually at the stage of their lives where they are not directly dependent on someone else organism for their survival, often found as larvae. But it is a lot it is possible for adult bottom organisms to be carried away during the process due to extremely strong currents, storms or nearby work which mix the bottom of the sea and all the organisms are located in the area (Matej, 2015).

When the ship arrives at the port of shipment releases the ballast, releasing at the same time all the organisms that contained in it (Kotrikla, 2015). It is worth mentioning, however, that the process of ballasting / disinfestation and the Ballast tanks are a very hostile environment for their survival organizations. This is due to the absence of light, oxygen and fluctuations of temperature during the voyage resulting in the majority of organizations does not survive until the next time the procedure is done cleaning. Dead organisms are consumed by necrophagous organisms or are decomposed by fungi and bacteria (Matej, 2015).

Those organisms that manage to survive and be released back into the sea difficult to adapt and survive in the new environment. The difference in species native species and predators, as well as in the conditions of the new environment make the survival of foreign organisms a difficult task. If they overcome these obstacles and kept alive, are likely to pose a threat to the young ecosystem. Organisms without natural enemies are a threat, because then begin to reproduce uncontrollably and cause increased competition with indigenous peoples for available resources.

1.7. The problems caused by bio-invaders

The seas and oceans are not closed systems, on the contrary they communicate between them with surface or deeper currents, resulting in millennia marine organisms have been dispersed in the oceans by natural means (cf. chapter 1.2.1). Nevertheless, due to the different conditions prevailing in Different parts of the world the diversity of ecosystems varies, such as these presented today. A typical example is the tropical zone, which separates the temperate zones of the northern and southern hemispheres and allowed in many species evolve independently, resulting in quite different marine biodiversity in the northern and southern hemispheres. (Kotrikla, 2017)

However, the continued growth of trade by sea, the need for savings money and time creating faster and bigger ships, they are decreasing more and more the natural barriers that restrict the movement of organisms. (Kotrikla, 2017). Thus, ships are a way for temperate and cold sea species zones to penetrate the tropics, and some of the most spectacular bio invasions concern northern temperate marine species invading southern waters and vice versa (Kotrikla, 2017) .

The biodiversity of marine ecosystems is affected by bio-invaders at the level of species, habitat and ecosystem. The ecological ones effects, therefore, are the disruption of the food web, acting either as predators or as competitors, carries a risk of introducing new diseases, which can destroy sensitive native species. Then the bio-invaders bring about changes in biodiversity and relative species abundance. The consequences of their introduction can also be economic, such as risk extinction of indigenous species with economic value, entailing costs for restoration of physical balance. There may still be danger transport or support of organisms harmful to human health, as well as also possible reduction of the tourist development of an area (Kotrikla, 2015).

All the above effects are combined to reduce the number of indigenous species of a habitat and replace them with "opportunistic" species - thus causing the homogenization of its ecosystems area. Also, these species can be toxic, such as the *Lagocephalus* fish that contains a very dangerous substance, tetrodotoxin, capable of causing serious Consumer health problems (Wikipedia, 2017).

1.8. The most basic examples of non-native species

The bacteria of Cholera (Cholera Bacteria) was introduced in South America and Gulf of Mexico, where it caused epidemics. From these epidemics there were 10,000 deaths. In 1991 the cholera epidemic spread to ports Peru and then in America killing hundreds of people (EMEDTV, Vibrio Cholerae Bacteria, 2017).

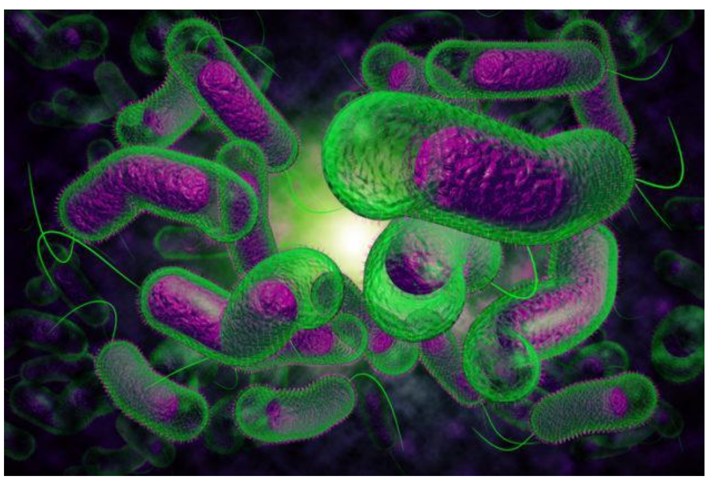

Figure 2 Cholera Bacteria (Home Remedies Guide, 2013)

The Crab (Chinese Mitten Crab - *Eriocheir sinensis*) is one of the most dangerous invasive species. Its natural reproductive environment is on coasts of North Asia and spread to Western Europe, the Baltic Sea and West coast of North America. This particular type of crab marks masses migrates for reproduction and creates nests on rivers causing corrosion. It feeds on native fish and invertebrates as a result their disappearance locally in periods of population growth (Kotrikla, 2017). It appeared in the West Coast of the United States in 1991 and in the East Coast in the year 2005 (USDA National Invasive Species Information, Aquatic Species, 2017).

Figure 3 Chinese Mitten Crab (Carly Brook, 2012)

To Green Crab (Green Crab) transferred from European shores in Australia and South Africa. These are the reasons for the development of his disease fatal cancer from which a large percentage of the population have become ill where these alien species have invaded. It hunts and feeds on bivalves and more crustaceans such as *molluscs* and scallops causing noticeable problem in diversity. (USDA- National Agricultural Library, National Invasive Species Information Center, 2017)

Figure 4 Green Crab (Thomson, 2016)

The zebra mussels (European Mussel - Zebra Mussel) from the Eurasia and transported to Canada in the Great Lakes region. They caused serious problems by blocking the water inlets in their pipes damage to the refrigeration systems of American industry. The Zebra mussels can also affect the environment of lakes and rivers where they are located. They feed on tiny food particles that filter out of the water, which can restrict food their larval forms of fish and other animals. Thus they cause increased aquatic life vegetation due to the high purity of the water.

Figure 5 European mussel (Zebra Mussels) (Invasive Species Council of BC, 2016)

Comb Warbler The (North American Comb Jelly, *Mnemiopsis leidyi*)comes from the East Coast of America and was transported to the Black Sea, Azovand Caspian Sea. Reproduced quickly(self-fertilizing hermaphrodite) under favorable conditions and feeds on zooplankton. It depletes zooplankton populations by altering food networks. It contributed significantly to the collapse of fisheries in the Black Sea 90s with strong economic and social influences. Now he threatens Caspian Sea (Kotrikla, 2017)

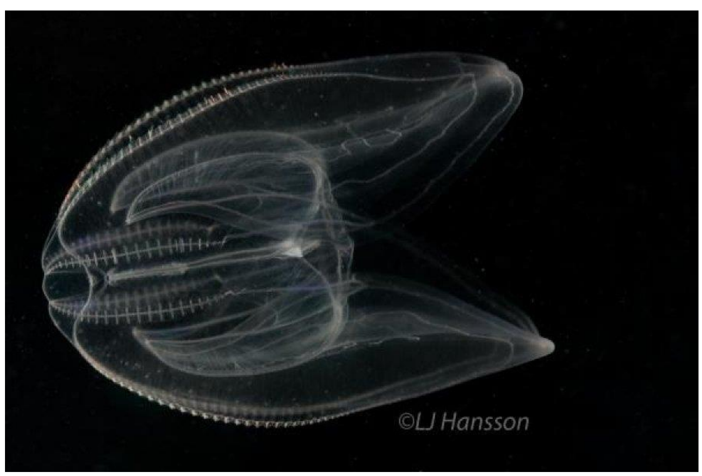

Figure 6 North American Comb Jelly (Marine Biological Laboratory, 2008)

2. THE REGULATORY FRAMEWORK FOR BALLAST MANAGEMENT

2.1. International Maritime Organization (IMO)

As mentioned in chapter one, the problem of alien species in the ballast water of ships due to a large extent in the increased volume of trade and its circulation in recent decades and, as volumes of maritime trade continue to grow, the problem may not have reached its culmination. It appears that the consequences in many areas of the world were catastrophic. Quantitative data show that the rate of bio-invasions continues to increase with alarming rate and constantly invading in new areas (IMO, 2017). The movement of non-native species is now recognized as one of the greater threats to the ecological and economic prosperity of the planet. These species cause enormous damage to biodiversity and its valuable natural resources land on which it depends. The direct and indirect effects on health are becoming more and more and more severe and environmental damage is often irreversible (IMO, 2017). Preventing the movement of foreign organisms and coordinating a timely one and effective response to invasions require input and cooperation between governments, economic sectors and non-governmental organizations. United Nations Convention on the Law of the Sea (Article 196) provides a global framework requiring states to work together to prevent, reduce and control the marine pollution, including intentional or accidental introduction of foreign or new species to a specific aquatic marine environment, which can cause significant and harmful changes to this (IMO, 2017).The International Maritime Organization (IMO) was at the forefront of the international undertaking to address their transfer invasive aquatic species (IAS) through shipping. In 1991, the MEPC (Marine Environment Protection Committee) adopted the international guidelines for preventing the introduction of unwanted aquatic animals and pathogens from ship ballast water discharges and sediments (MEPC resolution.50 (31)), while the United Nations Conference on the Environment and Development (UNCED - United Nations Conference on Environment and Development), held in Rio de Janeiro in 1992, recognized the issue as an important international concern (IMO, 2017).

In November 1993, the IMO Assembly adopted Resolution A.774 (18) with based on the 1991 guidelines, requesting the MEPC (Marine Environment Protection Committee) and the MSC (Marine Stewardship Council) to review the guidelines for international development legally binding provisions. Continuing her work for development of an international treaty, the Agency adopted the resolution in November 1997A.868 (20) - Guidelines for the control and management of ships ballast to minimize the transport of harmful aquatic organisms and pathogens , calling on its Member States to use these new guidelines for addressing the issue of IAS (Invasive Alien Species) (IMO, 2017) .After more than 14 years of complex negotiations between the states IMO members, the international convention on the control and management of ballast water and ship sediment (BWMC) during diplomatic conference held at the IMO headquarters in London on 13 February 2004. The Secretary-General of the International Maritime Organization stated that the new Convention will be an important step in its protection marine environment for this and future generations. "*The duty to our children and their children cannot be surpassed. We are sure that we would all like them to inherit a world with clean, productive, safe and safe seas - and the outcome of this conference, with the elimination of an ever-increasing one and more serious threat, will be necessary to ensure this* " (IMO, 2017).

2.2. Ballast Water Management Convention – (BWMC)

This convention ensures that all ship types will have to treat and disinfect the seawater used as ballast just before they discharge it to the ocean. This contract entered into force 12 months after its ratification by 30 states, which account for 35% of global merchant shipping. The contracting members are over sixty and represent the 68.51% of global merchant shipping) (IMO, 2017). The BWM Convention applies to all ships, including submarines, floating vessels, floating platforms, FSUn (Floating Storage Units) and of FPSO (Floating Production Storage and Offloading Facilities) (Lloyd's, 2016). Even though there are some specific exceptions:

a) Ships that do not operate in international waters
b) Warships, auxiliary warships (e.g., frigates, aircraft carriers)
c) Other vessels owned or operated by local state authorities (e.g., coast guard ships)
d) non – commercial domestic ships

e) ships that carry permanent ballast in sealed tanks

Compliance program:

From the moment the BWM Convention enters into force, all ships must manage the ballast on each trip either by exchanging it or by processing it using an approved ballast water treatment system. Alongside, it is necessary to revise certain provisions of the contract in order toto become functional and efficient. Its modification is deemed necessary because it concerns more than 50,000 ships which are called within the next five years to install a ballast water management system which can worth from $1 million to $ 5 million. After installation ship owners can be sure that the system they have chosen will be functional, as well as accepted by all regulatory authorities globally and especially in the USA (Karagiorgis, 2016). The compliance program for when a ship must treat the ballast is shown in the following table:

Table 1 Ballast treatment compliance program (Lloyds, 2016)

<table>
<tr><th>Ballast capacity</th><th>Existing ships Constructed (keel laid) before 2009</th><th>Existing ships Constructed (keel laid) in or after 2009 but before 2012</th><th>Existing ships Constructed (keel laid) in or after 2012</th></tr>
<tr><td>Less than 1,500m3</td><td>Entry into force (EIF) before 1 January, 2017: compliance by 1st IOPP renewal survey after the anniversary date of the delivery of the ship in 2016

EIF after 31 December, 2016: compliance by 1st IOPP renewal survey after EIF</td><td colspan="2">Compliance by 1st IOPP renewal survey after EIF</td></tr>
<tr><td>Between 1,500m3 and 5,000m3</td><td colspan="3">Compliance by 1st IOPP renewal survey after EIF</td></tr>
<tr><td>Greater than 5,000m3</td><td colspan="2">EIF before 1 January, 2017: compliance by 1st IOPP renewal survey after the anniversary date of the delivery of the ship in 2016

EIF after 31 December, 2016: compliance by 1st IOPP renewal survey after EIF</td><td>Compliance by 1st IOPP renewal survey after EIF</td></tr>
</table>

All vessels with a tonnage of more than 400 Tones will be required to have it on board an approved ballast management plan and a logbook of ballast water record book as well as to be researched and issued an international ballast management certificate. For ships whose flag management has not ratified the BWM contract, they can issue a certificate or a declaration of international conformity (IMO Certification) (Lloyd's, 2016).

- Ballast treatment technologies

Ships participating in a program approved by management may use standard technology for up to five years before requesting the installation of an approved treatment system according to the program compliance with Table 2.1. A standard system is a system under test and assessment to meet or exceed the requirements of Regulation D-2 (Lloyd's,2016).

As is well known the fleet of ships carrying bulk cargo is largest in the world in terms of capacity and a significant percentage of them uses the high energy efficiency marine ballast rejection system with the use of gravity for (topside ballast water tanks). These tanks are an integral part of bulk carriers. However, for the installation of a Marine Ballast Management System (BWMS) in a bulk carrier, which uses gravity to reject the ballast from the Top Side Tanks will have to overcome some technical challenges. The changes require substantial modifications to the ship's construction bulk cargo transport. Removing disposal systems using gravity, you will lose a significant advantage they offer, that of high energy efficiency (Koliomichou, 2017).

That is why *INTERCARGO* proposes for all the ships that are in operation, the use of an "extended ballast water exchange", only for topside ballast water tanks with the management of the remaining ballast is carried out by one system installed on all ships (as stated in the relevant Paper *MEPC71/4/19*) (Koliomichou, 2017). According to *INTERCARGO*, the international BWM regulation should takes into account that shipping is a capital-intensive industry and that it is not must bring about its distortion in the market by applying, influencing negatively the quality and viability of some bulk carriers (Koliomichou, 2017).

- Research and certification

All ships over 400 gt are subject to inspection and certification. Ships down of 400 tns will be subject to national research and certification schemes. The system research and certification under the BWM Convention is similar to the other IMO conventions. After completing the initial survey, it will be issued an International Ballast Management Certificate for a ship whose flag has not been ratified by the BWM Convention yet. For other ships, a new certificate will be issued in compliance for water ballast management. Both certificates as well as the declaration are valid for five years, and are subject to annual renewal. The IMO has published the provisional guidelines for investigations (contained in Circular *BWM.2/ Circ.7*) and is expected to integrate into the system harmonization guidelines for research and certification (*IMO resolution A.997 (25)*) (Lloyd's, 2016).

- Exceptions

Exemption may be granted to a ship or ships on a voyage or voyages in between designated ports or locations, or on a ship operating exclusively between designated ports or locations. An example of a ship that could qualify to this exemption will be a ship that trades exclusively between one or more ports (Lloyd's, 2016).

Any exemption granted is valid for a maximum period of five years such as subject to an interim review and provided that the ship does not mix ballast water or sediment other than between ports or sites set out in the exception. However, it should be noted that the exceptions may be revoked at any time by the competent authorities. To judge oneship suitable for exemption, a risk assessment must be carried out (*Riskin accordance with MEPC resolution.162 (56*) - Guidelines for risk assessment under Regulation A-4 of the BWM Convention (Lloyd's, 2016).

2.3. United States Coast Guard (USCG) Regulations

- Application

All ships arriving in US ports and plan to unload ballast water must perform exchange or treatment of ballast water other than management of their sediments. However, water exchange will only be allowed until the dates before start of the implementation of the processing (Lloyd's, 2016).

- Compliance program

The following table shows the dates on which vessels unload ballast in US waters required to install a treatment system (Lloyd's, 2016):

Table 2 USCG Compliance Program (United States Coast Guard BWT Compliance, 2016)

New vessels	Existing vessels where:	For other existing vessels	Existing vessels not required to have an IOPP certificate
Keel laid on or after 8th September 2017:	Completed IOPP renewal survey between 8th September 2014 and 7th September 2017:	Install BWM system at whichever occurs first of the following:	Tankers of less than 150GT and ships other than oil tankers of less than 400GT
Install BWM system upon delivery	Install BWM system at the first IOPP renewal survey on or after 8th September 2017	First IOPP renewal survey on or after 8th September 2019; OR Second IOPP renewal survey on or after 8th September 2017*	Install BWM system not later than 8th September 2024

- Exceptions

The following vessels are exempt from ballast treatment requirements, keeping reports and records (Lloyd's, 2016):

- ✓ Crude oil tankers engaged in offshore transactions and fishing vessels operating exclusively within a COPT zone (Captain of the Port). *(The term COTP is interpreted as the "captain" of the port, where is proportionate to the role of harbor master)*.
- ✓ Seagoing vessels operating in more than one COTP zone, do not operate outside the exclusive economic zone (EEZ) and are less than or equal to 1,600 tonnes of gross tonnage or less than or equal to3,000 tonnes (International Convention of 1969 for its counting ship tonnage, 1969).

Or non-seagoing ships:

- ✓ vessels undertaking and unloading ballast exclusively in one COTP zone.
- Extension

If the capabilities provided by the USCG are not practically feasible despite Shipowners possible request of extending from the USCG in respect of the implementation schedule. The availability of an alternative system management system use does not prevent the shipowner from receiving an extension. The regulations USCG provide is a procedure for applying these extensions on board (Lloyd's, 2016).

2.4. Regulations of the European Union

According to the European Commission, "invasive alien species are animals and plants that are introduced accidentally or intentionally into a natural environment where they usually do not exist under normal conditions and cause serious adverse effects in their new environment".

Regulation 1143/2014 of the EU (European Union) on the invasive alien species (Regulation (EU) No 1143/2014 of the European Parliament and of Council on the prevention and management of importation and spread of species) entered into force on 1st of January 2015. The Regulation “seeks to tackle the problem of invasive foreigners in a comprehensive way species to protect their natural biodiversity and services ecosystems, as well as to minimize and mitigate the negative impact on human health and economy that these can create issues ". The regulation states that" a large proportion of invasive species are imported involuntarily in the Union. Therefore, the most effective is essential management of inadvertent entry routes. Action in this area must be gradually, given the relatively limited experience in this field. Actions should include voluntary measures, such as actions proposed by the guidelines of the International Maritime Organization for the control and the management of biological pollution from ships, and mandatory measures. the action should be based on the experience gained in the Union and in the Member States with regard to the management of certain roads, including measures which established by the International Convention on Water Control and Management ballast and sediment of ships approved in 2004 ". (Lloyd's, 2016).

2.5. Regulation D - 2 in more detail

Ballast treatment management systems (BWMS) are primarily designed to comply with the ballast water standards laid down by Regulation D-2 of the BWM Convention and, in the case of the United States of America, "measures for foreign species in the ballast water of ships in US waters "are determined by the United States Coast Guard (USCG) as defined in the Federal Code (Batista et al., 2017).

Regulation D-2 is a measure for the release of water ballast, the which determines the permissible concentration of organisms during milking, and this standard applies to many size organizations. This template presents a large reduction in the concentration of microorganisms that present in ballast water, compared to untreated water. Such a reduction in the number of foreign organisms can released into an ecosystem is expected to reduce the creation of new invasions. This is one of the factors that affects the invasion and installation of non-native species, and these specific measures for unloading ballast have now been accepted, and must be achieved by every manufacturer requesting formal approval for its system (Batista et al., 2017).

According to him, there must be less than ten viable organisms per m 3 with a minimum dimension equal to or greater than 50µm. Alongside, less than ten viable organisms may be present per ml with a minimum dimension less than 50µm and greater than or equal to 10µm (Karagiannis, 2011). The ballast limits according to regulation D-2 are presented in detail in the following table *(D refers to diameter, CFU: Colony Forming Units)*:

Table 3 Microorganism limits of BWTS approval (IMO BWT Convention, 2017)

MICROORGANISM	UPPER LIMIT
D ≥ 50 µm	*10 org/m³*
10 µm ≤ D ≤ 50 µm	*10 org/mL*
Vibrio cholerae	*1 cfu/100 mL*
E. coli	*250 cfu/100 mL*
Enterococci	*100 cfu/100 mL*

2.6. Challenges

BWMS technologies must meet a number of specific requirements related to these regulations, where the main barrier is determined by biological performance tests in order to be evaluated. If the BWMS meets the specific standards for treated ballast based on the concentration of organisms then the BWMS is also called upon to succeed formal approval or certification prior to installation and use in oneship (Batista et al., 2017).

Through these activities, the recent announcement of the IMO emphasizes the importance of developing, testing and implementing BWMS from the industrial and shipping industries. However, in their view, construction and application, development and testing, as well as installation can officially approve. In fact, performance standards are critical points for the design, engineering, construction and operation requirements of the BWMS. Therefore, any uncertainty about performance standards should achieve a BWMS could greatly complicate the effective development and implementation of such systems (Batista et al., 2017).

At this stage, there is an international agreement on Regulation D-2in terms of IMO compliance standards, providing the industry with a relative fixed design goal. However, contrary to organic standards all BWMS systems must also meet the standards safety and environmental impact (e.g., safety of the ship and its crew and the release of chemicals into the surrounding waters). But despite the advice of the IMO for countries that have signed not to punish those "pioneering users" installed by first generation BWMS, manufacturers should take into account that performance standards and regulations may become stricter in the future. Thus, given the operational life of the ships, the manufacturers and shipping companies need to adopt a long-termoptics for ballast treatment, but also seek to comply with current ballast rejection standards (Batista et al., 2017).

The challenges of designing a BWMS with available technology are many aspects. BWMS must be serviced by different types of ships, effective for different categories of organisms (including different and distinct stages of their lives) and operate effectively and with safety under various ballast conditions (e.g., salinity levels, temperatures and flow rates). Although the future innovation and the latest technologies are often considered the most attractive approaches to solving such existing technologies should not be overlooked. Technologies ballast treatment should be based on basic and known physical, chemical and biological principles and must also meet the basic characteristics set out in required for commercial onboard technology, i.e. a system that is technically sound, environmentally friendly, practical (easy to train, operation and maintenance), functionally safe and of course with an acceptable finish cost (Batista et al., 2017).

Under normal operating conditions, uncertainties remain on the reliability, longevity and performance of a biocidal product approved BWMS after its start-up. In this context, aa recent study concluded that some type-approved BWMSs, despite proper installation on rated ships, they do not work satisfactorily and in the worst case they did not work at all. Similar conclusions emerged from the 2015 final report of the Maritime Protection Committee environment. Thus, regardless of the technical capabilities of a BWMS that are required to meet ballast rejection standards, including of the initial performance tests that meet the D-2 standards, the actual conditions in the world and human behavior can limit practicality system (e.g., training, operation, and maintenance), which in some can undermine the effectiveness of a BWMS (Batista et al.,2017).

In the future, such practical limitations could also carry stricter standards. USCG approved the first BWMS in 2016, but also stated in the "Practical Assessment" of May 10, 2016 that he knows that there is no technology available that meets the rejection standards more stringent than current D-2 standards. On these application issues in Act, October 8, 2015, the State of California passed a state bill which delayed the date of application for the final (stricter) standard performance of zero detectable living organisms on 1 January 2030, due to lack of available technology that can achieve this performance. There is, however, disagreement about the current capacity and performance of the available technologies. For example, unlike the releases of USCG and the State of California, the conclusion that emerges is that some existing BWMS can meet limits up to 100 times stricter than those of the regulationD-2. As stated in the IMO Final Report for 2015, among approved and commercially available BWMS used for reduction of the concentration of organisms in the ballast, devices are included filtering in almost 80% of the processing methods used by the ships in question, electrolytic disinfection devices at almost 40%, ultraviolet (UV) at 32% and liquid hypochlorite use at almost 17%of systems. Acoustic devices, heat processes, engineering or chemical deoxygenation and other less commonly used alternative technologies to represent a negligible market share (Batista et al., 2017).

Today, most approved BWMS and systems operate using a filtration combination followed by chemical treatment (e.g., electrochlorination, addition of active substances) or physical treatment using ultraviolet radiation. The filtering stage is targeted in retaining and removing organisms and suspended matter from ballast water, which is usually limited to orders of magnitude above 50 μm maximum dimension. Instead, the stages of chemical and physical processing have different principles of action. While the first stage causes cell division membranes and other cellular components, the latter induces damage directly to deoxyribonucleic acid and cell proteins. The goals of these approaches are either to completely destroy the organisms that exist in balm or damage them sufficiently so that they are not viable (ie., do not have the biological ability to live, grow and reproduce) (Batista et al.,2017).

2.7. Approval

The BWM Convention

Technologies developed for ballast water treatment are subject to approval through specific IMO processes and guidelines. These have been designed to ensure that these technologies meet the relevant standards of IMO, are sufficiently durable, have minimal adverse environmental effects and are suitable for use in the specific environment of ships.

Ballast treatment systems must be tested in accordance with the following IMO guidelines:

All systems:

- From the Guidelines for the approval of management systems of water ballast (so-called "G8 guidelines"). IMO resolutionMEPC.174 (58) revoking MEPC.125 (53).

In addition, for systems using active substances:

Instructions for the approval of ballast water management systems use the active substances (hereinafter referred to as "Guidelines G9 »). In accordance with the decision of the IMO MEPC.169 (57), which revokes theMEPC.126 (53) (Lloyd's, 2016).

According to the above the approval of a production model results from tests on its operation either on land before it is even installed or board the ship to ensure that its standards are complied with Regulation D-2.

- USCG Regulations

On the 2nd of December 2016 USCG gave the first type approval to the Optimarin system which works using ultraviolet radiation. The type approval of the Optimarin system is an important milestone that marks a step forward in meeting the needs of shipping industry in tackling the threat posed by invasive species and compliance with US law. Although the US Coast Guard marked a change with the issuance of the first type approval, the owners and operators have yet to assess whether the type-approval complies with operational needs of their ships.

The USCG requires ballast water to be treated with a treatment system ballast approved by the USCG, according to the schedule in Table 2. Recognizing that there were no USCG-approved systems until 2016, the USCG had provided guidance on how to apply for an extension which would allow ships to operate in US waters without treat the ballast water up to five years after the date of compliance in Table 2 (Lloyd's, 2016). At this point it is worth noting that the Swedish Alfa Laval and the Norwegian OceanSaver headquarters received approval certificate for Ballast Water Management

System (BWMS) from the United States Coast Guard Marine Safety Center. The certificates were issued after their applications were examined in detail whether the systems meet the requirements of the Regulation46 CFR 162,060. Already in December, the USCG issued the first certificate approval in Norwegian Optimarin for the Optimarin Ballast System (OBS).Alfa Laval's PureBallast 3 system incorporates UV reactors into four different sizes (170, 300, 600 and 1000 m3 / h) while it has capabilities at treatment range from 85 m3 / h to 3000 m3 / h. The initial approval concerns only systems using 300 m3 / h and 1000 reactorsm3 / h while the approval of systems with reactors 170 m3 / h and 600 m3 / his expected soon as it depends on the approval of relevant studies by the USCG (Nautical Chronicles, 2016). OceanSaver BWTS MKII is based on the principle of filtering and disinfection using electrolysis, where the oxidant is produced as disinfectant. This system has a processing capacity of 200 m3 / hup to 7200 m3 / h (Nautical Chronicles, 2016) .Both Alfa Laval and OceanSaver said they were ready to respond increased demand for these BWM systems caused by validation of the Ballast Water Management Convention (Nautical Chronicles, 2016).The ballast management system, developed by SunRui Marine Environment Engineering Co., Ltd, got the type approval from the Coast Guard USA on June 6, 2017, ranking the first manufacturer in Asia and fourth in the whole world. BalClor® BWMS applies technology side-flow electrolysis with a processing capacity ranging from 170-8500m3 / h. USCG Approved Ships Equipped with BalClor® BWMS meet USCG ballast water treatment requirements and are freely travel around the world, including its waters USA (SunRui Marine Environment Engineering, 2017). Ecochlor on August 18, 2017 was the fifth manufacturer in a row company that the BWTS system received USCG type approval. The Ecochlor BWTS uses a two-step process involving filtration and treatment with chlorine dioxide (ClO_2). The company emphasizes that the Ecochlor system provides shipowners some unique features. One of them is low consumption energy, perhaps the lowest in the industry. Typical power requirements for Ecochlor system that processes a total flow of 8,000 m3 / hr is 12 kWh, with the maximum requirements reach only up to 35 kWh (Green4Sea, 2017). In the same month, in August 2017, the SEACURE system of EVOQUA received and this is the final type approval by the USCG. The SeaCURE system is one of the smallest ballast water treatment systems based on electrochlorination and managed to complete the USCG tests with one unit capable of processing up to 6,000m3 / h from an easy to install system with dimensions of only 2m x 1.5m (Seanews Turkey, 2017).

Nevertheless, to avoid imposing sanctions on ships that already have install a processing system approved by another flag authority, the USCG introduced the alternative management system (AMS). Some important facts about AMS are given below:

MS AMS are ballast water treatment systems that have been accepted for use in US waters by the USCG

A AMS is a temporary solution until approved ones are available in USCG systems

A AMS approval does not necessarily mean that the system will succeed USCG type approval

Each ship with AMS installed can use this system only for a period of five years after the date on which the ship would otherwise have to comply with the standard USCG rejection (Lloyd's, 2016).

2.8. Ballast Water Management Plans

All ships of 400 gt and above must have on board an approved ballast management plan for the ship and a logbook for ballast water to comply with the BWM contract. The Management Plan Ballast Water requires (Lloyd's, 2016):

✓ A ship certificate that complies with international regulations in order to the risk of harmful aquatic organisms is minimized and pathogens in ship ballast water and associated sediments

✓ Identification of the person in charge of the ship's ballast

✓ Examination of the safety data of ships, provide information to PSC officers on its ballast handling system confirm that ballast water management can effectively planned

✓ Staff training in BWM operating practices

✓ A transcript written in the working language of the ship. If the language is not English, French or Spanish, a translation must be included in one of these languages.

2.9. Sampling and analysis

- The BWM Convention

IMO guidelines for ballast sampling and analysis are given in the G2 guidelines. The purpose of this guide is to provides general recommendations on methodologies and approaches to sampling and analysis in order to test compliance with the standards set described in Regulations D-1 and D-2 of the BWM Convention (Lloyd's, 2016).

Sampling and analysis for compliance testing is a complex one issue. According to the guidelines, the compliance test can be carried out in two stages. An indicative analysis of ballast water discharge can be done as a first step to determine if oneship may comply with the BWM contract prior to a detailed analysis. In the conformity test, the sampling protocol used should result in a representative sample of all of it quantity of ballast loaded, from any tank or any combination of ballast landing tanks (Lloyd's, 2016).

- USCG Regulations

The USCG assesses compliance as part of its regular inspection of its ships. This compliance approach follows a similar regime for all other equipment inspections. In general, a Coast Guard inspector may check the documents, including the certificate of approval AMS acceptance letter, and confirm his / her knowledge crew on the use of the equipment and its condition. If the results of this inspection are not satisfactory, the USCG will get samples from the ballast unloading to check that the system is working Efficiently. It should be noted that the USCG continues to grow faster and accurate sampling and analysis methods (Lloyd's, 2016).

In addition, the USCG and the Environmental Protection Agency (EPA-Environment Protection Agency) signed the Memorandum of Understanding in 2011 on with the EPA General Vessel Licensing Program (VGP- Vessel General Permit). The VGP program entered into force in December 2013. The memorandum allows USCG and EPA to combine compliance efforts and exchange information. VGP requires ship operators to control systems themselves ballast water treatment. This includes functional testing and analysis ballast water samples to confirm biological performance and that concentrations of residual chemicals are within limits (Lloyd's, 2016).

2.10. Port authority

- The BWM Convention

From the moment the BWM contract entered into force (September 8, 2017), ships may be subject to inspections by port authorities in order to determine whether they comply with the requirements of the BWM Convention.

These inspections are limited to:

Verification and certification of ship

Ballast water record book inspection

Ballast water sampling according to the IMO guidelines.

In 2014, the IMO (IMO) adopted guidelines for the control of port authority under the BWM Convention (MEPC resolution.252 (67)). That's all provide basic instructions for conducting port State control inspections to verify compliance with the requirements of the BWM Convention. This is not going to limit the port authority rights with regard to verification of compliance with the BWM convention (Lloyd's, 2016).

- USCG Regulations

It is necessary to submit a report to the USCG COTP (Captain Of The Port) 24 hours before the ship arrives in a US port. The ship must provide access to the COTP vessel for sampling of ballast water and sediments, review documents and conduct other surveys to assess compliance with USCG requirements (Lloyd's, 2016)

2.11. Compliance Planning

1. The shipowner's obligations under the Contract must be signed BWM in all national and local regulations. According to the BWM Convention, shipowners must (Lloyd's, 2016):
   - ✓ Ensure that all ballast landings comply with Regulation D-1 or D-2, i.e. the ballast is replaced or existing treatment: this obligation applies to ballast discharges in either open sea or in the port.
   - ✓ Ensure that the procedures of the Water Management Plan Ballast are always followed.
   - ✓ Keep the appropriate records in the Ballast Record Book
   - ✓ Operate and maintain ballast water treatment systems according to the manufacturer's instructions.
2. The ship's ballast tank, pumps and piping

It is necessary to control ballast tanks and pumping networks and piping on board to identify any changes required for achieving compliance with the BWM convention.

It is necessary for the shipowners to give special attention to the following:

A. Reusable tanks, for example, those that are used for ballast and storage purposes occasionally found in gray water color and / or black: should not be mixed in different water types should not and should only be discarded accordingly regulations.
B. Injectors used for Stripping ballast tanks (Tank in which all the liquid inside can be pumped and not some residue is left): it is common practice to use local seawater in the injector, and so it was decided that the ballast water discharged during the Stripping tank operation may not be a real representation of the contents of the ballast tanks as it is mixed with the water that used for this purpose. Therefore, it should not be done sampling during operation of Stripping tanks (Lloyd's, 2016).

3. Development of a Water Ballast Management Plan

The next step is to develop the Water Ballast Management Plan in an initial stage. It can then be revised as the preparation for compliance and may be modified by additional information depending on the processing system selected for installation, safety and mitigation issues, passenger training requirements and the name of the water ballast manager (Lloyd's, 2016).

4. Selection and installation of a ballast treatment system

The selection and installation of a processing system requires careful consideration examination and planning. You will need to ensure that the required resources are available when needed, that plans are submitted to the class on time for approval and that the system and any ancillary equipment are delivered to the ship according to schedule (Lloyd's, 2016).

5. Develop training for ship crews and ensure adequate training in BWM companies.

Appropriate staff training program should be developed and included in the Water Ballast Management Plan. The crew should is trained in its obligations under the BWM contract, companies operation on board, operation and maintenance of the treatment system ballast, as well as any safety hazards associated with armature companies or the processing system (Lloyd's, 2016).

6. Preparation of a final management plan

A final version of the Ballast Water Management Plan must be created, obtain the required internal approvals and submit the plan for approval to the classification society or the flag, as the case may be submitted in a timely manner to avoid any delays (Lloyd's, 2016).

7. Research and certification

When all the compliance preparations are completed, it's the right time for to arrange the initial inspection of the ship for the issuance of an International Certificate of Ballast Management or Certificate of Conformity (Lloyd's, 2016).

8. It is necessary to fully understand the obligations of the shipowner in accordance with USCG regulations:

If ships approach US ports and plan to unload ballast, water exchange or ballast treatment must be carried out in addition to sediment management. However, water exchange will only be allowed until application boundaries for treatment systems. Another method accepted by USCG for ballast water management is the use of drinking water (from municipal system of North America). However, ballast tanks must be cleaned of any sediment prior to this application. The USCG requires also: Water Ballast Management Plan, clean ballast tanks without sediments, and a report to be submitted to US authorities 24 hours before they arrive in a US port (Lloyd's, 2016).

2.12. Achieve compliance during system operation

1. Ballast water and sediment management according to the Ballast Water Management Plan:

It must be verified that the management of all ballast discharges and sediments are made in accordance with the requirements of the BWM Convention and in accordance with procedures of the approved Ballast Water Management Plan. Still, it is needed to archive of sedimentation and sediment management companies to be correctly recorded in the ballast logbook.

2. The Ballast Water Management Plan and the Logbook are required to be kept up to date:

It is necessary to conduct periodic audits of the Ballast Water Management Plan and be updated as necessary. Where required amendments must be approved.

3. It is deemed necessary that the required investigations be carried out within deadlines,

ie to organize in time the required annual, mid-term and review evaluations and be ensured that take place within the permitted dates.

4. Use and maintain the equipment according to the instructions of its manufacturer:

The ballast water treatment system should be operational and maintained properly according to the manufacturer's instructions. The procedures of the approved Ballast Management Plan will reflect this requirement.

5. Monitoring the performance of the processing system:

System performance should be monitored using installed monitoring equipment, meters or sensors. The parameters that monitored system will vary depending on the type of system is installed. Includes: flow rate / flow rate, percentage dosage of the active substance, neutralizer dosing rate, consumption energy, TRO (total residual oxidant), and PH (acidity / alkalinity). Having the system maintained and monitored by the manufacturer on a regular basis and having carried out periodic biological tests efficiency, will also help ensure that the system will continue to operate as designed and certified (Lloyd's, 2016).

3. Ballast Water Treatment Methods

3.1. Factors for the suitability of the ballast treatment method

When a shipping company enters the method selection process ballast that will use one of its ships, it is necessary to make sure it meets certain conditions. In particular, of primary importance is the safety of the ship and the crew as well as the impact of the method used in the environment (to fix more environmental issues than it may cause). Still, immediately next important criterion for the suitability of a processing method is the cost that will requires and of course its biological efficiency (the microorganisms are unable to settle in other ecosystems or moving away from ballast or by exterminating them) (Kotrikla, 2017)

3.2. Basic methods

In response to D-2 Regulation (see Chapter 2), it has been developed in recent years a number of technologies [eg in 2015 about 50 trading systems are reported which have been checked]. Many of these technologies have already been implemented with success in drinking water treatment (for example filtration, chlorination or ozonation) or urban wastewater and were adapted to their specific needs (small space, optimal cost - performance ratio and high performance due to the D-2 standard requirements). Still, others had no precedent on land and developed for on-board application only (eg deactivation using inert gas from the ship's exhaust) (Kotrikla,2015).

A classic on-board ballast treatment system uses two or more methods together to ensure that the ballast meets the requirements of IMO. It is worth noting that many processing systems may not be able to reach such a stage as to be promoted to market, nevertheless a dynamic market has been created around BWMS, facing new data and regulations that change very regularly (Matej, 2015).

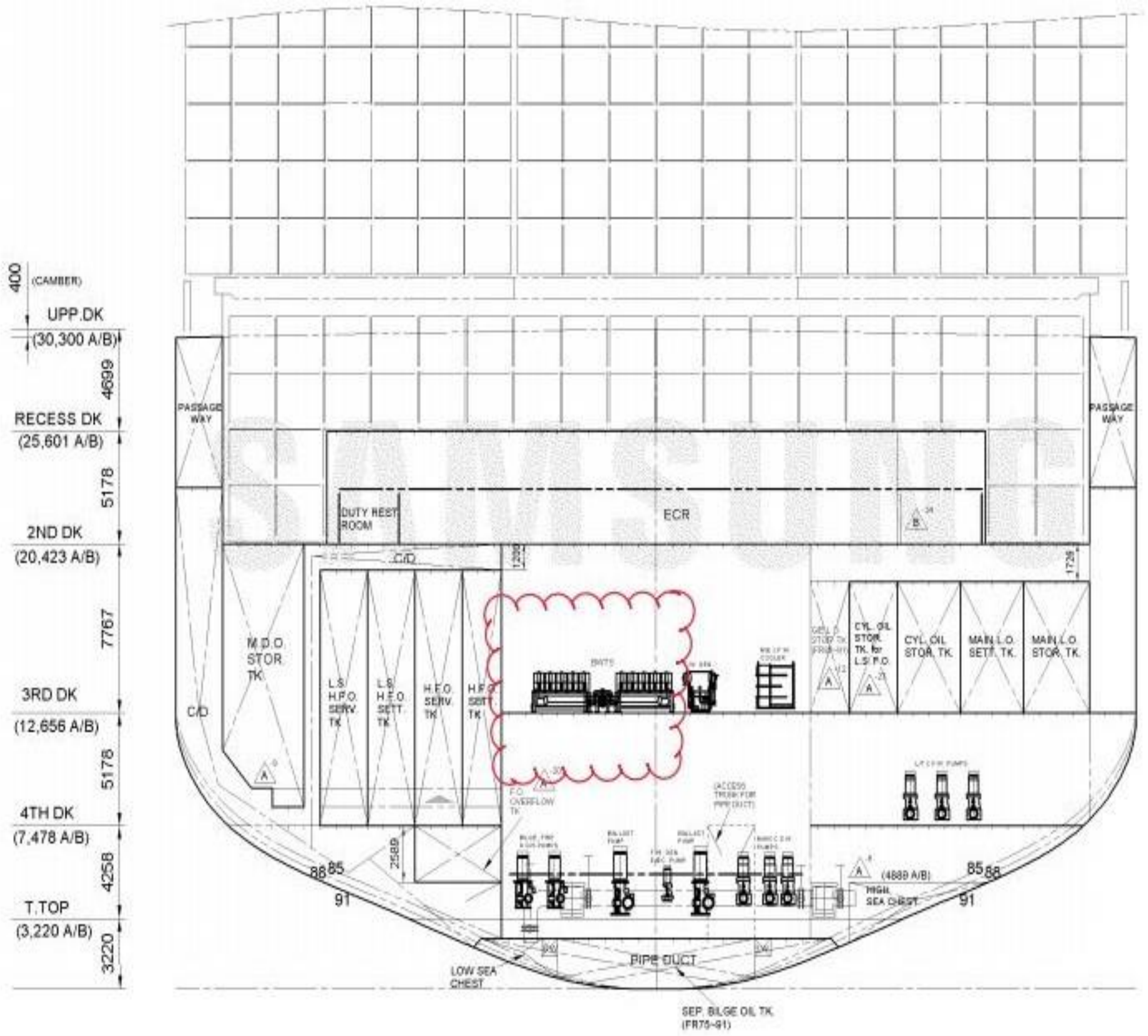

Figure 7 A highlighted BWT System from Samsung Shipyards, Republic of Korea

In general, the technologies used to treat ballast water are divided into two major categories, the natural separation of liquids/solids and disinfection/sterilization. In physical separation it is important to remove as much solid element as possible from the ballast thus each system can operate more efficiently (eg in the UV system cannot treat the ballast properly as long as there are solid objects inside water, this happens because the ultraviolet light cannot reach everywhere as in the shadows are created in water by some objects) (Matej, 2015). This happens usually either by surface filtration by membranes or by cyclonic separation (Kotrikla, 2015). Then in the sterilization process (using natural ingredients) or disinfection (using chemicals), both aim to remove or to exterminate the organisms in the ballast. More specifically, Technologies that can be used to treat ballast are:

- Smart engineering tools such as:
  - ✓ Using filters or hydrocyclone technology
- Physical processes, such as:
  - ✓ Heating
  - ✓ UV rays
  - ✓ Ultrasound/Cavitation
  - ✓ Degassing with Inert Gas
- Chemical, such as:
  - ✓ Using oxidizing biocides (eg chlorine, its chlorine dioxide, peroxyacid (CH3CO-OOH) and hydrogen peroxide(H2O2) or ozone) which act by destroying cellular structures, such as cell membranes.
  - ✓ Non-oxidizing biocides, which interact with reproductive, nervous or metabolic functions of organisms (eg. Menadione / Vitamin K).

More specific, the ballast treatment methods are the following:

3.2.1. Mechanical processing

1. Filtration

The filtration method appears to be the most environmentally friendly but the amount of ballast that needs to be filtered is huge. The filtered solids and waste from cleaning the filters (backwashing discarded either in the area from which the ballast is obtained or further processed on ships prior to unloading (Marine Insight, 2017). Advantage of this method is that the retained organisms can return to their natural ecosystem when disposed of during the sealing. If the ballast is filtered during its extraction, their proper disposal required to minimize the accidental entry of various heterogeneous organisms (Marine Ecology Progress Series, 2001). The new filtration technologies allow the separation of organisms over a certain one size (eg usually used automatic, self-cleaning filters with pore size about 40 μm) (Kotrikla, 2015). So this method is effective in filtering larger organisms. The disadvantages of this method are: of filtering is the high cost of the mechanisms to be installed, the pressure drop, the reduction of the ballast inlet flow in the tanks due to the blockage of the filters and the inability of the filters to trap very small organisms, such as viruses or bacteria, and in toxic algae (Kotrikla, 2015) . The filters have little impact in terms of effects in human health and their nature is not permanent (Karachalios, 2017). Usually is not used as the main technology for ballast processing and work in addition to other processing methods or using physics or chemical treatment.

Types of filters used:

- Filtration using sand filters.
  This type of filter is a classic, old method used for drinking water and wastewater treatment, and can reduce the number of organisms and turbidity before the disinfection effect. This mechanism works by mechanically holding organisms larger than filter pores and trapping some smaller organisms in spaces of filter resources. But the speed of the water passing through the sand filters are extremely high (5 - 30 m^3/hour) and their efficiency is not satisfactory. This prevents the introduction of microorganisms with a dimension of up to 60 μm in the ship's ballast network (Hyde Marine, 2017).

- Metallic nets

This type of filter holds organisms 10 - 20 μm without the need of adding any chemical compound.

- Special membranes

By using special membranes even bacteria can be retained and absorbed by the membranes. Their pores are about 0.2μm. Nonetheless, a first filtration needs to be done to remove the solid bodies and waste from water while the cost is quite high for this method (Study, 2008).

2. Hydrocyclone

Separation by hydrocyclone technology (or centrifugation) is based on density differences and separates organisms and sediments from ballast water (Tsatsanis, 2016). The ballast is ejected tangentially to the upper part of the cone construction and performs a spiral movement downwards (Figure 7). The floating particles, due to their higher density/mass, are ejected into the walls of the cone and are collected at the bottom, while the ballast overflows (Kotrikla, 2015). This method traps particles in the order of size 50 to 100 μm (Tsatsanis, 2016) . Of course, with the use of this system many microorganisms escape and enter the ballast resulting in this method by itself may not be enough. Hydrocyclones are less effective from the filters, in terms of the efficiency of their removal. More in particular, the challenge facing these systems is that many tiny aquatic organisms have a density close to that of seawater, making them difficult to remove using separation systems through hydrocyclones. Such technologies can be used in combination with other disinfection or sterilization technologies, as they are very effective in removing larger organisms (Karachalios, 2017).

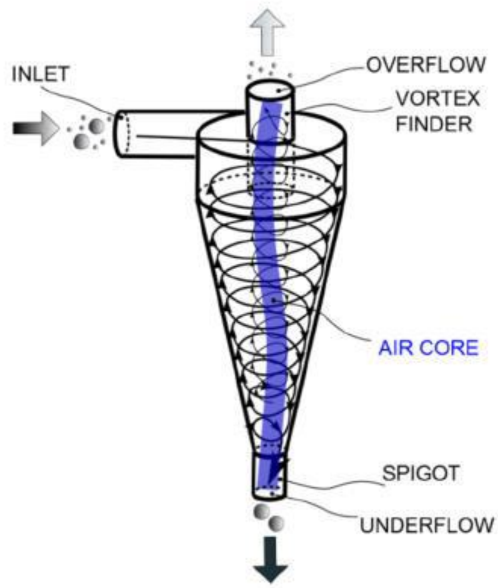

Figure 8 A hydrocyclone setup (Karachalios, 2017)

3. Coagulation

Seawater contains suspended material in colloidal dimensions (<1 μm). With the addition of flocculant (salts of ferrous iron or aluminum or a polymer) the repulsive forces between the colloidal particles are neutralized, so that they approach each other and agglomerated, thus increasing their size. The advantage is the increase the size of the colloidal material that improves filtration performance. However, an additional water storage tank may be required, along with sufficient residence time to complete the flocculation process (Kortrikla, 2015). Nevertheless, flocculation is not used in any ballast treatment system nowadays (Lloyd's, 2017)

3.2.2. Physical treatment process

1. Heat treatment

With the method of heat treatment, their neutralization is achieved of foreign organisms in ballast tanks by heating the water to a very high temperature before it returns to the sea.

The options available for ballast water heating are currently two:

(1) the use of heat dissipated generated by the machines of the ship and

(2) the use of heat generated by auxiliary boilers to be installed on board (Prince William Sound Regional Citizens' Advisory Council, 2005).

An extremely good choice is to use the heat generated in the main engine of the ship as well is undesirable for machines (Tsatsanis, 2016). Its temperature ballast entering the ballast tank (Ballast Tank) is about25TheC but of course not high enough to neutralize the microorganisms. Therefore, a percentage of the order of 20% is used to flow from the cooling system of the main engine at a temperature of 80 °C.. Advantage of the method is the fact that no differences arise with chemical by-products. Heat treatment has the added advantage of heating it sediment contained in ballast water and killing NIS (Nonindigenous species) found in the sediment (Prince William Sound Regional Citizens' Advisory Council, 2005). In the first case which is the possibility of using heat from The ship's engines are certainly presented as the most cost effective solution because it exploits heat that was otherwise considered unwanted and unnecessary.

Nevertheless, in this case a large amount of ballast water has to be treated at very high temperatures and additional thermal power may be required to effectively kill a wider range of NIS (Non-Indigenous Species) and a ballast water a simple system with heat exchanger is not enough. Then, additional heat installations can therefore be installed to develop a high temperature capable of killing all microorganisms, ie auxiliary boilers so as to heat the water in higher temperatures than a simple heat exchanger can deliver exploits the heat emitted by ship engines (Prince William Sound Regional Citizens' Advisory Council, 2005).

Important: The voyage of the ship must be large enough to allow water to reach the set temperatures for the required time.

According to experiments performed using the ballast heat treatment, it turned out that staying in ballast water for four days at 35 °C, kills80% of microorganisms, a day and a half at 40 °C, kill 90%. That's all rates are unacceptable for ballast treatment in the shipping industry according to the International Maritime Organization (IMO) where it has established rules on the management and treatment of ballast and sediments (eg D2 Standards). The effectiveness in killing microorganisms is against95% approach if kept for four hours at 45 °C (Annals of DAAAM for 2012).

One idea for improving this ballast treatment system is to there is a ballast tank that will be suitable (ie intended for this purpose) to heat the water. In this way, after completion of treatment, clean ballast water (ie that which has undergone treatment) can be transferred to another tank. So there will be the possibility to introduce in the ship another quantity of ballast that would also pass in turn the heat treatment.

Due to this time delay, the ballast treatment method with heating is suitable for those types of ships that have small quantities ballast water for treatment, for example container vessels (Container Ships) and general cargo ships (General Cargo Ships). On the contrary, in high-capacity ships, such as oil tankers that unload all cargo at the same time, they must perform a sealing process by filling ballast reservoirs with seawater (Annals of DAAAM for 2012).

Researchers suspect, but have not fully documented, that its heating ballast can increase system corrosion and promote growth of algae that thrive in heat. Heating water in tanks ballast of old ships can cause serious safety problems due to of the unknown effects of corrosion. Also, in case it is used auxiliary boiler for water heating or fuel consumption for systems high flow is estimated at over 475 gallons per hour to increase water temperature from 4 °C to 66 °C (Prince William Sound Regional Citizens' Advisory Council, 2005).

Boiler installation cost estimates depend on each boat. Ships (with diesel engines) can have it anyway installed boiler that produces steam for other functions, eg fuel heating to flow, engine heating, seawater heating that with its evaporation produces fresh (drinking) water. This boiler can operate either on its own fuel, or to take advantage of the heat from its propulsion engines ship (Prince William Sound Regional Citizens' Advisory Council, 2005).

2. Ultraviolet (UV) rays

Ultraviolet light is used in hospitals to kill the microorganisms and protect against the spread of a disease. The method is very effective in microorganisms (Kotrikla, 2015). It has been observed that this ballast treatment technology has extracted a considerable attention and seems to be more preferred in conjunction than filtering the ballast before UV treatment.

Advantages of ultraviolet technology are as following:

- Extermination of microorganisms in a satisfactory percentage.
- Easy system to maintain.
- Safe for the crew and understandable to use with minimal human monitoring.
- It has been tested and proven to be reliable many times and has been checked on land before on board
- It is a purely natural method of water treatment. No carcinogenic by-products are created.
- Not affected by the degree of salinity or pH.
- Does not corrode the ship.
- The UV system does not require transport, storage and there are no harmful chemicals
- No risk of overdose (chemical)
- UV technology does not change the physical parameters of water like pH value, temperature, salinity, taste, smell or color
- UV ballast treatment is not affected by fluctuations, while salinity that may be present in the water from different ports (Optimarin Presentation, 2017)

Most systems that use chemical components are affected by the presence of salinity in the seawater. On the other hand, the UV as well as the mechanical methods are not affected by the difference of chemical characteristics of each sea area.

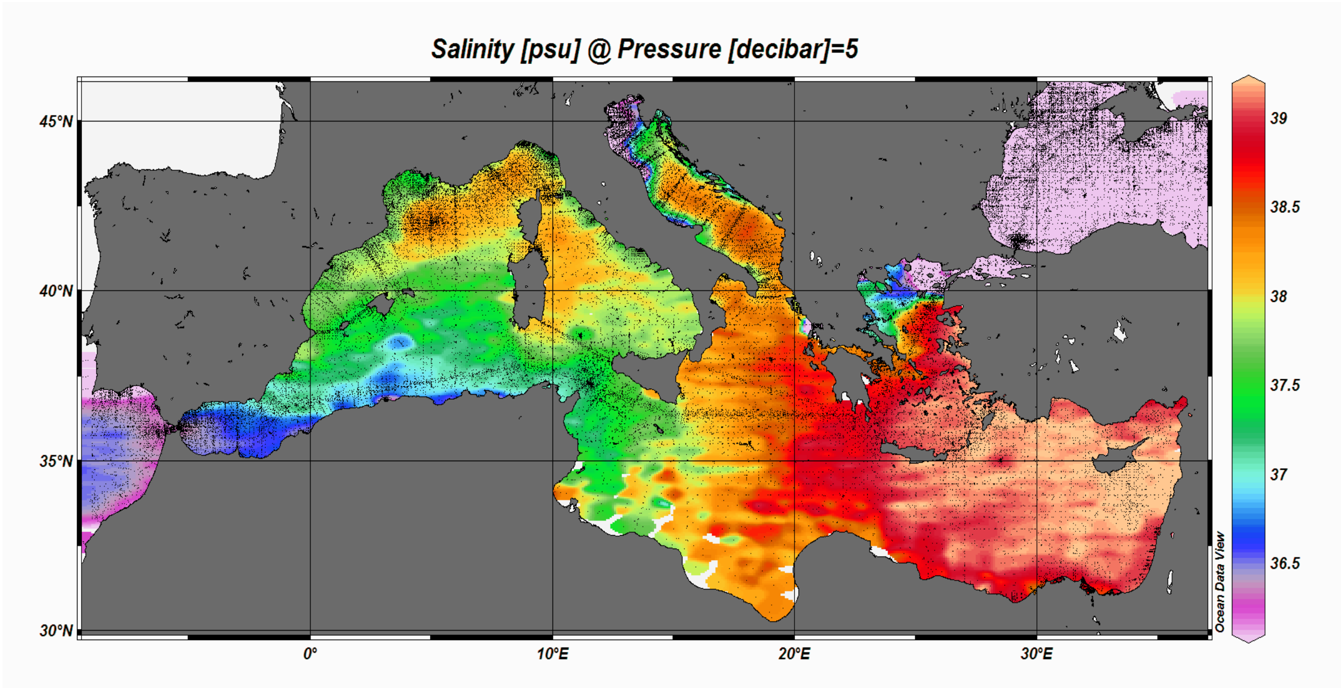

Figure 9 The salinity map of the Mediterranean Sea (MedatlasII)

Meanwhile, the main operating costs for BWTS based on ultraviolet radiation related to energy consumption. Shipowners can reduce prices reducing the intensity of ultraviolet radiation, provided that the ballast water of the ship unloaded still complies with Regulation D-2 (International Maritime Organization, 2008a). It is therefore interesting determine the lowest lethal dose of ultraviolet radiation and estimate the time required to neutralize the organisms when stored in ballast tanks after irradiation. UV radiation performed either with low pressure ultraviolet lamps (LP - Low Pressure) or medium pressure (Ranveig Ottoey Olsen et al., 2015). Manufacturers take care of UV lamp to have a long life (at least 4,000hrs) (Panasia, 2015).

On the other hand, research has shown that ultraviolet radiation can leaves cells in different conditions (alive, dead or damaged), where the viability of damaged cells during evacuation is uncertain. The damaged cells may be uncultivable, although they may have metabolic activity and may pose a health risk. Further, the cellular mechanisms of DNA reconstruction can be restored genetic information causing cell growth and reproduction after evacuation. In addition, the terminology that describes the organisms in rejection can be confusing or vague. The IMO contract where refers to "sustainable" organizations and guidelines for approval of ballast management systems (G8) define "sustainable organisms" as "Organisms and any stages of life of those who are living". The USCG also uses the term "living" (Ranveig Ottoey Olsen et al., 2015).

The following are some of the factors that can help prevent some from installing a ballast treatment system with the method of ultraviolet radiation, these are:

- The need increased power supply.
- Increased maintenance and installation costs.
- Does not respond positively to cloudy water as UV radiation absorbed or dispersed by the suspended particles of water
- If the power of the radiation is low the water passes through UV without disinfection
- It takes up a lot of space on the ship

The manufacturers carefully studied the above parameters managed to configure systems that bypass these difficulties (eg Panasia with the GloEn-Patrol system).

In the early market, the UV system was known to be unsuitable for high water capacity ships due to high energy consumption and fingerprint. The footprint, in m^2 , is the area it occupies a ballast treatment device on board. Now the systems have improved in the market and ships of either small or large capacity are installed the filtration + UV method (eg Optimarin, Panasia, Alfa Laval).

Another improvement of the UV lamp BWTS (Ballast Water Treatment System) is addition of small concentrations of H_2O_2 (hydrogen peroxide), leading to improved treatment with ultraviolet radiation. However, the operating cost per 1000 m^3 treated water was estimated for the typical cargo ships up to 14 € for UV treatment and 16 € for UV / H_2O_2 treatment.

Indicative cost of a UV ballast treatment system ranges from309,995 to 476,800 €, as well as indicative maintenance costs for a system with lamps life of 5000 hours amounts to 7,000 € per year. In addition, the operating costs of the machine must be taken into account can reach even €20,000 per year.

3. Ultrasound treatment

The method of cavitation uses ultrasound, ie mechanical waves which create areas of lower or higher pressure as they propagate in ballast (Kotrikla, 2015). High pressure ultrasound is used for destruction of microorganisms by oscillating in the liquid exposed to ultrasound (Study, 2008). The low pressure can be such that the water to evaporates locally, creating water vapor bubbles. If these bubbles formed in the body of microorganisms, cell destruction occurs of their membranes and death (Kotrikla, 2015).

More specifically, when the bubbles reach a volume at which they can no longer absorb energy, collapse violently during a high cycle pressure (compression phase). This the phenomenon is called cavitation. During the explosion are achieved very high temperatures (about 5,000 K or 4726.85 °C) and pressures (about2.000atm) (Hielscher - Ultrasound Technology, 2017). In terms of acceptance from an environmental point of view, there are no known or expected environmental concerns related to ultrasonic cavitation technology.

Advantages of the cavitation method are:

- ✓ No chemicals are used
- ✓ It is an environmentally friendly method
- ✓ It is effective and valid.
- ✓ Safe and easy to use.
- ✓ Strong and reliable.
- ✓ Ability to scale to any size

Studies of combined processing technologies have shown that ultrasound works very effective in combination with other ballast treatment methods, such as ozone, chlorination, ultraviolet light, temperature or high pressures. Because of the easiness of installation and low space requirements, ultrasonic equipment is ideal for upgrading and upgrading existing systems ballast treatment (Hielscher - Ultrasound Technology, 2017).

A total of 14% of the systems on the market operate by the cavitation method and ultrasound effect (Lloyd's, 2017).

However, the stress on the ship's walls is created during ultrasound and cavitation. Therefore, it should not be ignored the potential health and safety risks as well as potential effect of repeated exposure of the ship's hull to high wave length frequency (Aleksandar Vorkapić et al, 2016).

4. Deoxygenation

As the name implies, the ballast treatment method with deoxygenation involves the removal of oxygen from the ballast water tanks for causing suffocation of organisms. This is usually done by injecting nitrogen or any other inert gas in the area above the water level on ballast tanks.

It is important to consider the following:

It generally takes about 2-4 days for the inert gas to lead to suffocation organizations. This method is usually not suitable for ships that have short trips. The application of deoxygenation is performed mainly either during the trip or when receiving the ballast, where again it takes some days to until completed. Several BWTS used his deoxygenation method water, as a promising technology for ballast water treatment of ships. However, the complete deoxygenation time may not be applicable for a universal application of this treatment, which should preferably be used for ships that make longer voyages in cold environments. However, time for a full deoxygenation may not be applicable to a universal application of this which should preferably be used for ships that make longer trips in cold environments. Based on studies 35%of the systems performs the processing during the trip and during the recruitment. The treatment while receiving the ballast may not give the necessary time to deactivate/neutralize the organisms while the trip takes more than 4 days for the method to be effective (Lloyd's, 2017).

In addition, this type of system can be used on ships with absolutely sealed ballast tanks. If one is already installed on a ship inert gas system, then a deoxygenation system will not require more space (Marine Insight Equipment Watch, 2017). Deoxygenation is environmentally friendly and has the potential save money by preventing rust on board, especially when nitrogen gas is used, as there is its added advantage enrichment of the nitrogen content of the ballast water and its reduction corrosion caused by the presence of oxygen. Deoxygenation studies show successful results in killing a variety of foreign organisms (Prince William Sound Regional Citizens' Advisory Council, 2005).

Nevertheless, some species, such as those found in the form of cysts or anaerobic bacteria (which do not need oxygen to survive), may be able to survive in the conditions in a Nitrogen-treated ballast tank (Prince William Sound Regional Citizens' Advisory Council, 2005).

When ballast is sealed, inert gas enters the water ballast using a Venturi tube (Venturi tube is a device for the measuring the flow of a fluid consisting of a tube with a short, narrow one center section and widened conical ends so that a fluid flows through of the central part at a faster speed than through an extreme part creates a pressure difference and thus the flow of the fluid is measured (See Fig3.3), the oxygen concentration levels of the water decrease, and the water sterilized. Even during the trip, the ballast tanks are enriched with inert gas so as to prevent the growth of each organization. Thus, the ballast that has been deoxygenated during degreasing returns to the sea again passing through a Venturi tube which enriches again water with atmospheric air.

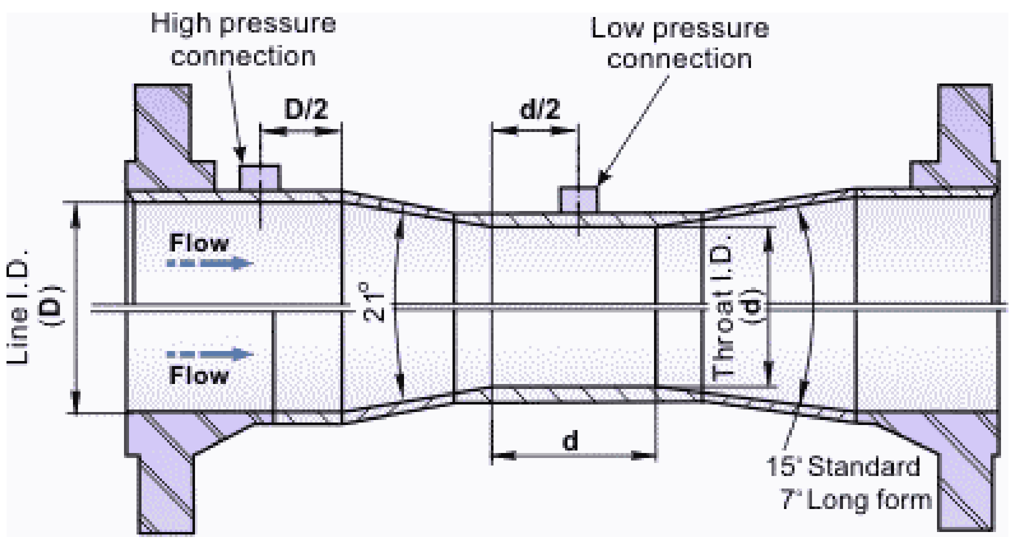

Figure 10 Venturi tube effect (Reader-Harris, 2011)

3.2.3. Chemical Treatment Methods

Chemical biocides can be used to neutralize pests in the ballast of ships. The choice of the type of chemical biocidal product must be done very carefully, so as not to create risks for man and the environment. These chemicals are provided in solid form or as concentrated liquids so that they can be easily stored on board (Kotrikla, 2015)

1. Chlorination

Among the chemical disinfection methods, chlorination was the most preferred. Chlorine can be produced from sodium hypochlorite, electrolysis, etc. dosages are about 2 mg / l. Chlorine disinfection is an effective method used in drinking water systems (Kotrikla, 2015).

Bacteria removal efficiency is 85.2% for *Escherichia Coli* and 99.85% for anaerobic bacteria recorded by aqueous ballast tests using sodium hypochlorite. The chlorine efficiency depends on temperature, reaction time and residual chlorine as well as the pH (Kotrikla, 2015).

The by-products of chemical disinfection using active substances are a significant problem, which is taken into account in the type - approval process ballast treatment systems. The manufacturers of the systems claim that the produced concentrations of chlorination by-products will not create a problem in the marine environment (Kotrikla, 2015).

In any case, it is not allowed to create a new form of pollution in effort to address the negative environmental impacts of ship - unloading procedures on ships (Kotrikla, 2015).

Other oxidizing chemicals used for disinfection are chloride, ozone, bromine and hydrogen peroxide. The tests chloride dioxide recorded a 98% subtraction of foreign organizations (TRANSACTIONS ON MARITIME SCIENCE, 2016).

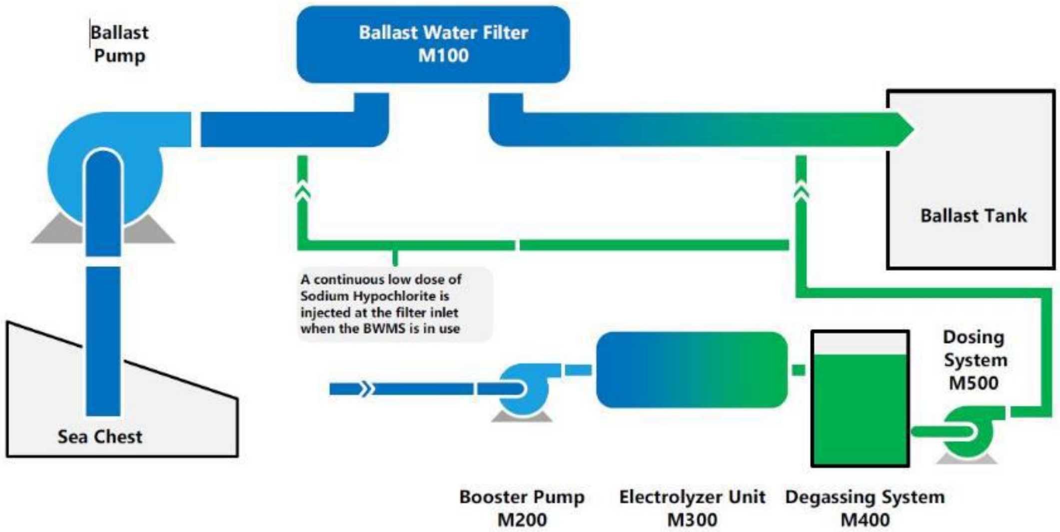

Figure 11 Chlorination System (Drydock, 2018)

2. Electrochlorination

Electrochlorination is an effective, safe and simple method for ballast treatment. It is worth noting that after UV treatment is the most popular ballast treatment method and occupies 22% of the market BWT systems (Lloyd's, 2017). In this method, chloride chloride(salt) of seawater is converted to sodium hypochlorite in order to prevent the growth of aquatic organisms. Free chlorine and its derivatives kill almost all aquatic organisms so that their final concentrations meet the IMO D-2 setting. According to foaming, the remaining hypochlorite solution is neutralized by the addition neutralizing chemical that removes all other oxidants that can be harmful (TRANSACTIONS ON MARITIME SCIENCE, 2016).

Advantages of the method are the following:

- ✓ There is no restriction on the flow of ballast water.
- ✓ Supply of residual disinfectant to ballast tanks for protection against the re-activation of organisms.
- ✓ As sodium hypochlorite is produced by seawater itself through electrolysis, there is no need to handle and store on the ship harmful pesticides, while the exclusive use on board ensures that production is limited to meeting demand only which reduces the energy consumption requirement (Evoqua Water Technologies LLC, 2017).

Ballast water electrochlorination treatment systems redirect a small stream of water in electrolytic cells where sodium hypochlorite is produced and injected into the ballast before entering the tanks. Disinfection of the tank can significantly improved by adequate control of sodium hypochlorite. An important advantage of electrochlorination over UV technology is that only one process is sufficient to achieve a satisfactorily low number organisms in the reservoir (TRANSACTIONS ON MARITIME SCIENCE, 2016).

Natural seawater has, with some exceptions, a pH typically around 8, and therefore a low $[H^+]$ (hydrogen cation) available to react. Based on both the HOCl (Hypochlorous Acid) Decomposition Reaction as well as the principle of Le Chatelier, the formation of HOCl will be reduced because of it shift of equilibrium to the formation of hypochlorite ion (ClO^-).Since ClO^- is a disinfectant several times less active from HOCl, its electrochlorination efficiency is expected that natural seawater will always be reduced due to the relatively low H +(Batista, William R et al., 2017) .In fact, the pH problem associated with efficiency of electrochlorination in seawater raises further technical problems and additional process, such as carbonation, ie immediate injection of carbon dioxide (CO_2) into the ballast water used for maintaining the low pH of the ballast water, ie higher H^+. However, additional and necessary equipment must be properly installed and the process must be controlled and monitored. Finally, the cost and the Electrochlorination disinfection efficiency must be obtained definitely take into account when trying to understand its effectiveness procedure (Batista, William R et al., 2017).

The above factors are not the only ones that affect its efficiency of the electrolytic disinfection process. The temperature of ballast water is also an important and often overlooked factor who is directly related to the fact that lower temperatures reduce the molar concentration of hypochlorous acid (HOCl) favoring the existence of ClO species. In addition, the presence of other naturally occurring anion species in seawater competes with the anion region and reduces the effectiveness of this process. For example, bromide anions, in combined with dissolved organic material, can produce extremely harmful by-products (eg different bromides and tri-halomethane), which may contribute to increased levels of hazardous disinfection by-products during abortion (Batista, William R et al., 2017) .Another complex aspect of electrochlorination procedures is the possibility accelerated corrosion rates of carbon steel due to corrosion effect of oxidizing agents such as Cl_2, HOCl and ClO^- produced during duration of ballast treatment. Indeed, the IMO suggested suitable one's corrosion checks by BWMS applicants as a precautionary measure, as well as increased corrosion rates have the potential to intensify structural damage to ballast tanks and the pipeline network, thus jeopardizing structural integrity of ships. The consequence of these additional controls is its further increase costs of maintenance and preventive protection against corrosion, ie dyeing and anion killing (Batista, William R et al., 2017).

Disadvantages are also its complexity and aggression sodium hypochlorite. When shutdown is required or during of waxing, these systems use neutralization because the Sodium hypochlorite is an undesirable substance for the marine environment. Another disadvantage is the salinity of seawater required for hypochlorite production and sometimes an additional tank is required to maintain the sufficient salinity of seawater. Thus, this method presents difficulties in its application in fresh or brackish water and in this case high energy consumption is required (TRANSACTIONS ON MARITIMESCIENCE, 2016)

Figure 12 Electrochlorination system by ERMA First Technologies ESK, Piraeus GR

3. Ozonation

Ozone is a colorless oxidizing biocidal product with a strong odor and is formed of course in the earth's atmosphere. It has very unstable properties even when injected into water decomposes quickly. Ozone has been found to be one of the strongest and faster oxidants that oxidize microorganisms and particles present in the water such as mold, yeast, organic matter, viruses, etc. (Marine Insight Equipment Watch ,2017). As for the ozone generator, it is a gas-producing engine generated ozone using oxygen from the atmosphere.

The principle of the generator is as follows: Electricity is used evacuation field together with the ambient air flowing through its cells ozone responsible for converting and increasing the amount of gas ozone. Ozone is then injected into the ballast water with an infusion unit. The Ozone dissolves in water, reacts with organic matter and kills organisms present in the water and thus makes the ballast safer to be released into any ocean water (Marine Insight Equipment Watch, 2017). May be required the installation of ozone generators for large quantities of ballast, which is expensive and demanding in space (Kotrikla, 2015).

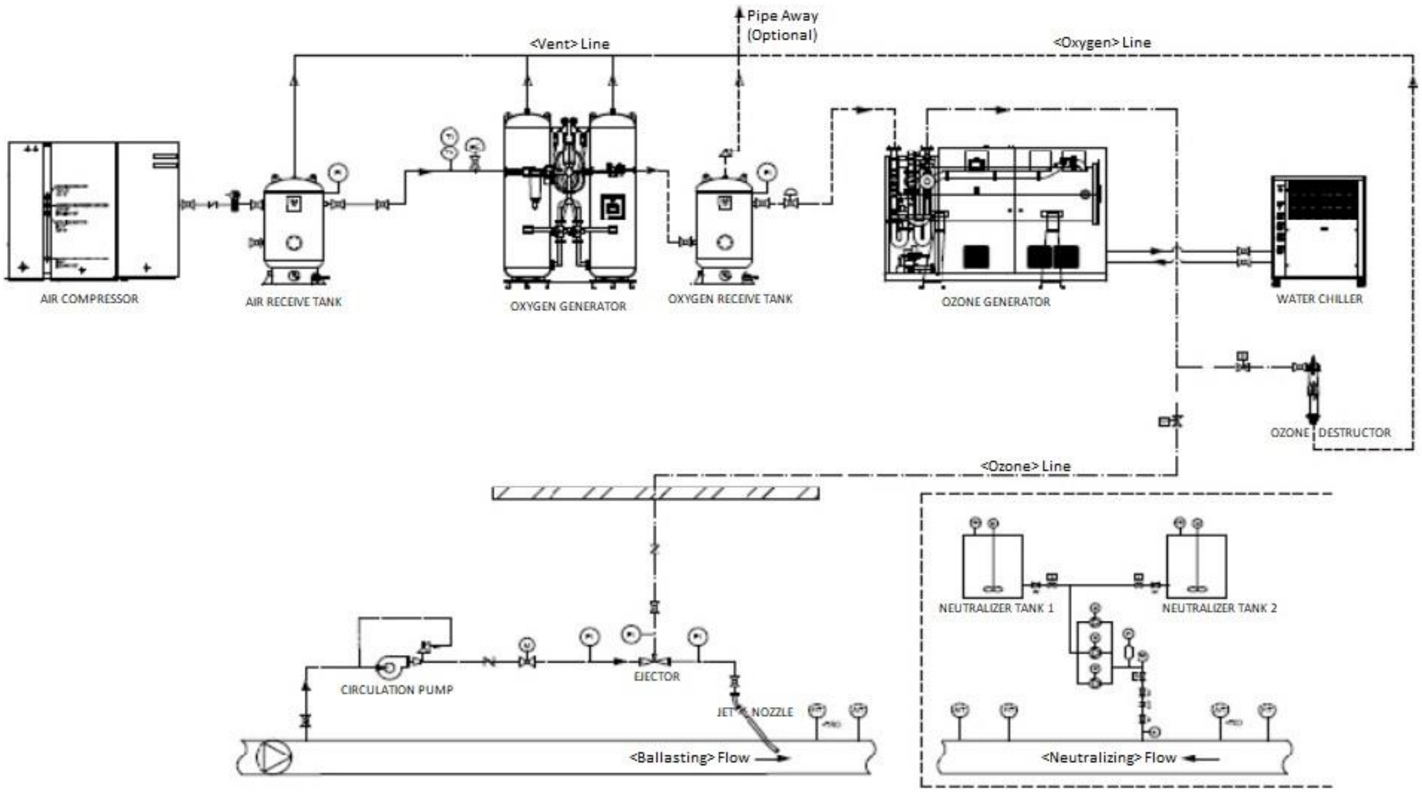

Figure 13 Ballast water ozonation system schematic diagram by NK Technologies, Japan

The basic system layout (Figure 13) includes an ozone generator, an injection unit, a line filter and a neutralizer. The line filter is placed in front of the ozone generator and the injection unit which separates from the ballast either organisms or objects of larger volume while the neutralizer is placed on the ballast system finish line. The neutralizer comes into operation during onboarding from the ship. Neutralization is because ozone is a toxic gas and can harm humans and environment if left in the ballast during and after ablation. The Ozone generator system is more effective in removing larger ones when combined with other processing methods, such as electrolysis or UV methods (Deacutis et al., 2002).

Challenges to using ozone include the fact that it reacts with bromine ions in seawater and produces bromoform, can cause erosion problems in tanks and is not effective against cysts from *Dinomastigotes* (Deacutis et al., 2002).

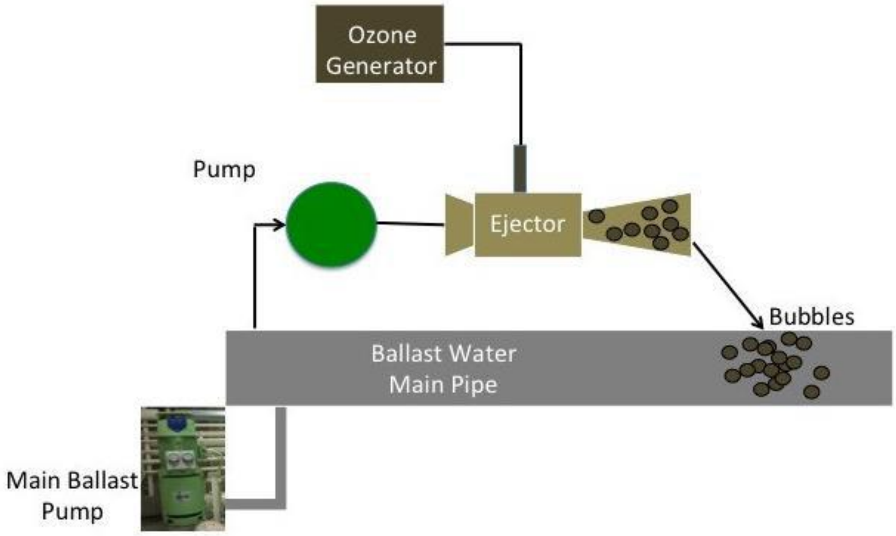

Figure 14 Illustration in a simplified form of an Ozone System (Marine Insight, 2017)

Also, this processing method may require a neutralization process of ozone when releasing ballast water back into the sea.

3.3. Classification of Ballast Treatment Systems

There are fifty-seven in the trade in Ballast Processing Systems manufacturers who have developed systems based on combination of two or more processing methods and this is the case for ensuring the effectiveness of a system whose cost is high enough.

The following figures give a clearer picture of their numerous systems that are commercially available to date, based on the Lloyd's report for 2017 (Lloyd's, 2017).

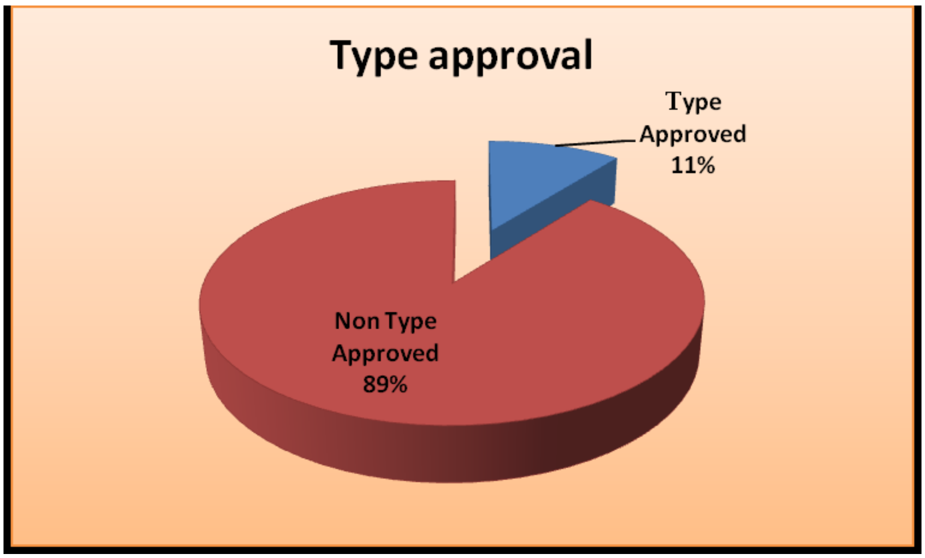

Figure 15 Classification of ballast treatment systems for Type Approval

-All systems: 57

-Type Approved: 6

-AMS Approved: 47

Type Approval:

The process by which a State certifies that a type of vehicle, system, component or separate technical unit complies with the relevant administrative provisions and technical requirements.

AMS Approval:

AMS is a provisional name given to a ballast water treatment system which has been approved by a foreign administration. AMS is a system of approval by Americans only (American Coast Guard). Vessels operating in the waters of the USA may use a BWMT system specified by the AMS for management of their ballast discharges instead of ballast water exchange -for a period of five years from the date of conformity of the ship - while the system BWT undergoes USCG type test. AMS certification is not guaranteed either implies that USCG type approval is possible, as both programs are independently of each other (Trojan Marinex, 2014). In case, that someone installs an AMS system right now and the supplier does not receive eventually the USCG type approval for this system as a consequence, you may need to remove from the ship. It is also written in American law that after the existence of an approved type system is no longer allowed to be installed AMS system (Kiukas, 2017).

➢ Approved :47

➢Non approved: 3

➢ In progress :1

➢ Nil :5

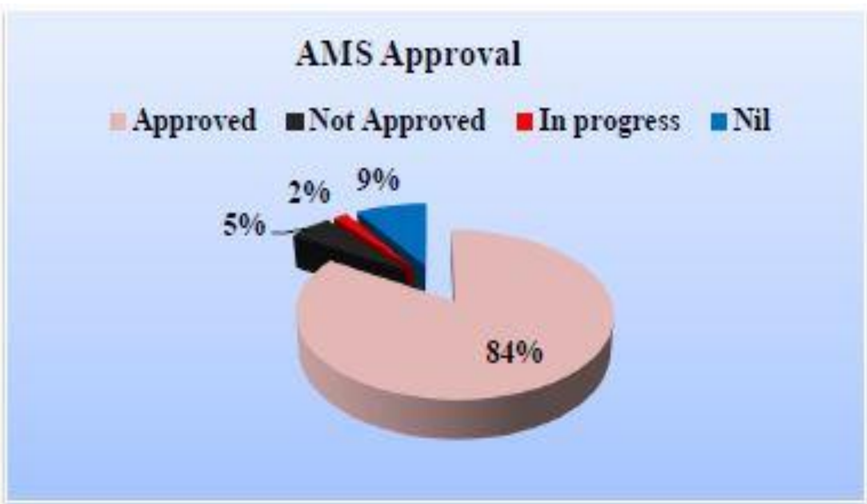

Figure 16 Classification of BWTS systems for AMS (Alternative Management System)

The percentage of AMS Approved systems is clearly higher compared to the percentage of Type Approved systems. This is obviously because of the ships who had already installed a ballast treatment system could not be excluded from the US Coast Guard. Nevertheless, this is temporary as well a ship with an AMS installed can use it in US waters for five years after the date on which otherwise had to comply with the USCG standard (Kotrikla, 2015). So far, about 85% of systems have got an AMS approval (Lloyd's, 2017).

For a system to meet all USCG requirements and obtain approval from the USCG has proved to be a particularly difficult case as only 5% of systems that have been marketed were deemed appropriate and received type approval (Lloyd's, 2017).

Figure 17 Classification of BWTS systems for G8 approval

The G8 Guidelines for the approval of management systems addressed primarily to the Administrations or to the authorized people in order to assess whether water management systems comply with the standard as defined in Regulation D-2 of the International "Convention on the Control and Management of the Ballast of Ships and Sediments", known as the "contract" (BWMC) (IMO, 2017).

The guidelines contain general requirements on design and construction, technical procedures for evaluation and process of issuing the type-approval certificate of the management system water ballast (IMO, 2017).

The next figure shows the percentage of systems that have received the generalG8 approval. 93% of the systems have received the approval of the guidelinesG8 lines while only 7% were not considered suitable and did not meet the regulation criteria.

Ballast Treatment Systems (BWTS) on the market:

Despite the fact of the ever-changing regulatory framework around BWMT the ballast treatment systems market is experiencing great growth such as shown in the diagrams below (Lloyd's, 2017).

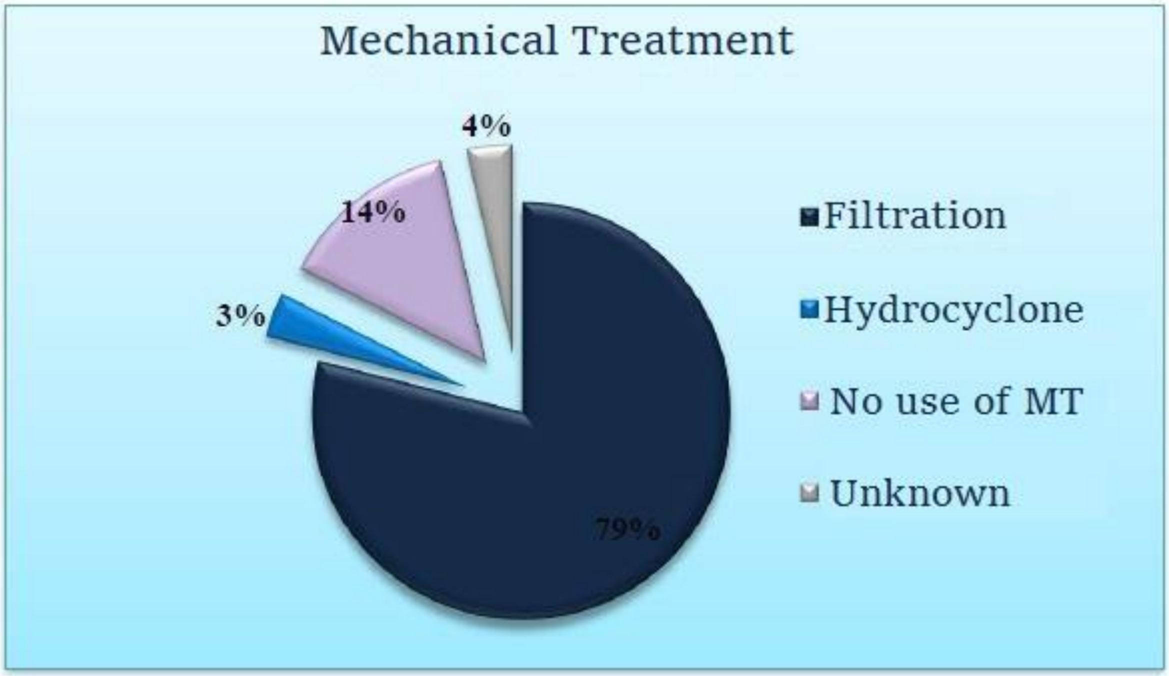

Figure 18 Classification of Systems in terms of the use of Mechanical Separation.

As shown in the diagram above 82% of the systems use as the first stage of mechanical separation processing either using a filter or in a small percentage using a hydrocyclone. Only 4% do not use any kind of mechanical separation (Lloyd's, 2017)

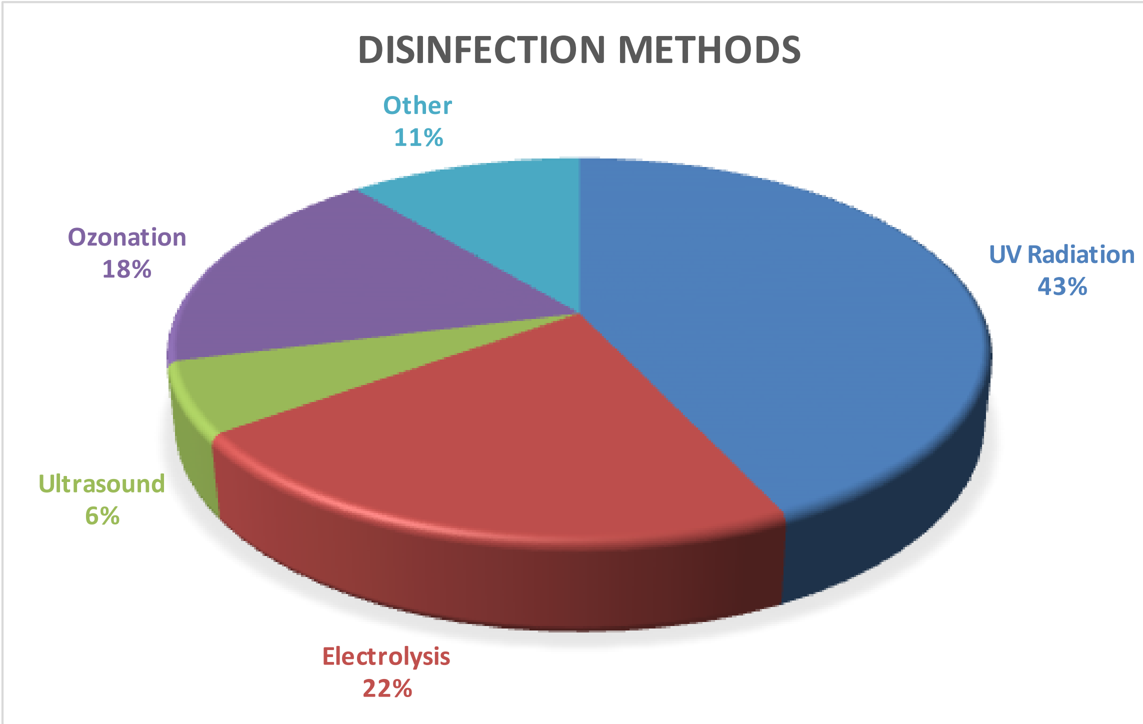

Figure 19 Classification of ballast treatment disinfection methods in the market.

The most popular method of ballast treatment is ultraviolet (UV) rays as shown above at 43%, and electrolysis follows at a rate of 22%. These two methods have been judged as the most suitable for the immediate neutralization of foreign organisms in the ballast. It is worth noting that the press approval from the USCG has been given to three manufacturers both of which use Electrolysis/Electrochlorination and one ultraviolet (UV) rays. In addition, ozonation consists of 18% of market's percentage while the 11% of ships prefer other alternative treatment methods (Lloyd's, 2017).

3.4. Conclusions

Until two years ago, the US Coast Guard had not judged any system that is suitable to receive the final Type Approval. However, at 2th December 2016 USCG gave the first type approval to the Optimarin system which works using ultraviolet radiation.

The type approval of the Optimarin system is an important milestone that marks a step forward in meeting the needs of shipping industry in tackling the threat posed by invasive species and compliance with US law. Although the US Coast Guard marked a change with the issuance of the first type approval, the owners and operators have yet to assess whether the type-approval complies with operational needs of their ships.

After December 2016 until January 2018, another five were approved ballast treatment systems and represent 7% of the total systems on the market.

The sales of the systems in the market showed a rapid growth and especially after the approval of systems by 6 different manufacturers the position of the shipowner is now facilitated. Most will only turn to purchase of reliable systems that meet US regulations Coast Guard. The fact that systems of different methods were approved processing option allows shipowners to decide which system will be better for each ship.

According to Figure 6 almost all systems, regardless of the method used, require the installation of special filters to prevent penetration of large organisms and the ballast to continue to the final processing.

In conclusion, after the BWMC entered into force in September 2017, the picture created by the US Coast Guard with the rigor of its measures improved after finding reliable systems and allayed his concerns world of shipping. Despite this, of course, there is still concern on whether shipping will finally be able to meet this challenge the cost but also whether these systems will really help to reduce the movement of foreign organisms.

4. Selection of a ballast treatment method

4.1. Introduction

An acceptable solution to the environmental problems associated with its ballast was the adoption and proper use of approved designs and systems ballast management and processing (BWMS). As mentioned before chapter on September 8, 2017 the management contract entered into force and treatment of the ballast of ships of the International Maritime Organization and in accordance under this Convention ships engaged in international trade must have an approved BWMS system to discharge ballast water while reducing the transport of items. In response to the enormous global concern about the problem this, the vast majority of BWMS, currently approved by International Maritime Organization (IMO) and the United States Coast Guard, uses as its main function two main technologies (electro-chlorination or ultraviolet radiation) treatment often used in conjunction with filtration. However, both technologies have been challenged in this regard with their practical effectiveness, and the method of electro-chlorination and for the potential environmental impact of ballast unloading.

Therefore, selecting the appropriate ballast treatment system requires individual research for each ship separately as the type plays a special role of the ship and the company profile of its manager. The cost of installation of such system leaves the shipowner with an extremely small margin of error due to the high cost of the system and its installation.

4.2. Ballast Treatment Systems (BWTS) Concerns

IMO approval requirements for ballast water treatment systems compare estimated exposure levels of individual substances with potential their toxicity, which is criticized for its simplification, as it exists limited risk assessment such as energy consumption, atmospheric pollution or waste generation. The IMO has set standards for approval ballast water management system, as regards the toxicity of the water which caused by the active substances and related by – products were used. However, for most processing systems ballasts using oxidizing compounds, the formation of chemical by-products (CBPs - Chemical By-Products) is an issue and can cause adverse effects on aquatic organisms. There is also a concern about certain disinfection by-products (halogenated), such as dibromochloromethane and sodium bromide. The use of active substances as disinfectants against non-invasion indigenous species through disarmament can have adverse effects to organisms living in the landing area, even when active substances are neutralized by a reducing agent, such as sodium thiosulfate. The regular ballast evacuation enriched with toxic substances in ports and their sinuses can cause eutrophication and changes in the microbial community, especially in colder areas (Karachalios, 2017).

There are concerns about the effectiveness of the BWTS. In 95% of certified BWTS, the unloading criteria could be met even without ballast processing, indicating that the certification program for these systems is dysfunctional in protecting human health. In another case, the processing administered by a prototype system ClO_2 , was generally effective against plankton organisms, although the bacterial communities recovered after a few days. There are also arguments that the degree of adverse effects that neutral active substances in aquatic organisms depend on them water quality factors such as salinity, alkalinity and organic matter compounds in water. The results show that contrary to current methods risk assessment, temperature and ice concentration at sea determine the suitability of ecosystems for 61% of species, not saline (11%). Eventually, some concerns were identified about its construction structure ship damage and ballast treatment systems. In 2012, about 68 different BWTS were available, of which 75% were system processing was based on ultraviolet inactivation or use chlorine as active substance, which were found to cause corrosion of ballast tanks, due to their strong oxidative capacity. In this case, of the neutralization of microorganisms by ultraviolet radiation, the percentages corrosion increases slightly. It has also been found that the processing methods ballast water with continuous disinfection, could cause damage to tank walls (Karachalios, 2017).

In addition, there is a possibility that some risks will be underestimated and they are important to closely monitor marine and coastal ecosystems, even after the imposition of the BWMC. For example, coastal routes not subject to ballast water exchange and carried out directly River-to-river route should be considered dangerous for introduction of NIS (Non-Indigenous Species), if the source waters may contain invasive species. This control must be carried out properly by the port authorities in each port in order to obtain reliable analyzes from ballast sampling. The installation of BTWS on ships also raise straining, safety, maintenance and challenge concerns ship repair personnel with limited knowledge in this field (Karachalios, 2017)

4.3. Installation of BWTS in reconstructed (Retrofit) old ship

A ballast treatment system (BWTS) installation project in one already existing ship (in this case it is a conversion) includes several stages such as evaluating possible solutions and selecting the appropriate system, design and installation possibilities.

The time estimates for the research of installing a BWTS on ships Reconstruction varies, but should take about nine months if the process is carried out in a systematic way aimed at the most appropriate solution, the which is always specific to each ship. After its entry into force contract there may be congestion in the market due to the huge increase demand. The lack of sufficient resources to deal with the current burden work of the classification societies involved, the plethora of sellers, the time installation, the docking of the ship (as system installation is done in the vast majority of it during the tanking of the ship (Dry dock) can all contribute to delaying its completion specific project on board.

In the first phase of the BWTS reconstruction process, a list is provided options with the best alternatives for each ship. The choice for the configuration of the list of options is based on various techniques and economic criteria. Different systems, methods and manufacturers are compared. Also, operating costs are taken into account, the footprint of the required equipment and its functional characteristics such as water quality, total volume ballast which can be processed per year. A 3D scan is performed and3D models of different systems are formed in a virtual point on the ship generated by 3D scanning. The BWTS usually require space for their maintenance and repairs. Adequate space availability for maintenance can be controlled with 3D design.

The final choice is made from the alternatives selected according to routine trade negotiations and decisions.

The design begins with updating the relevant diagrams systemic. Possible incompatibilities with other systems or piping must are detected as early as possible, so accurate methods are preferred design. Laser scanning is a proven tool for creating an exact starting point for the design which is preferably done at3D. The longer the incompatibilities are identified, the greater the impact in terms of time and cost. Another important issue is the plan transport. The components of the system are large and the transport may not be is possible through regular routes (Bachér et al., xx).

After sending the system diagrams and other plans for approval by the classification society, installation and preparation planning begins. The detailed design has a significant effect on successful installation and complete the system installation project on a rebuilt oneship. The better and more careful the design, the less time spent at the yard, where the installation normally takes place. The best design is essential for its successful and timely completion installation (Bachér et al., xx).

So, the shipowner's main concern is to find a BWTS that meets the rules of the IMO authorities and flags, as well as specific requirements for ships, including the characteristics of the water in which it operates system. The selected system should, having preceded the above process, be cost-effective and the operation of the system should not create problems in the existing ship systems or require additional efforts by the ship's crew.

Following the above should be considered summarized below questions before selecting a system from the respective shipowner (Team, 2011):

I. <u>Has it been approved?</u>
   To install a BWTS on board, it must have received approval by a recognized body in accordance with the relevant IMO guidelines. If the system uses any active substance, must have received final approval from the IMO before type approval approved.

II. Does it have enough capacity?

All BWTS have Total Capacity (TCR)Rate). This indicates how many cubic meters of ballast water can edit the system every hour. A system will need to be selected with TCR high enough to handle the total amount ballast of the ship and ballast capacity of the ship and the operational pumping rate.

III. Is it safe against gases on board?

If the ship is a tanker and the system is to be installed in a "dangerous gas area" (ie in the cargo area), this system must be certified "safe with respect to volatiles of volatile components ".

IV. How much space does it require?

The system footprints range from about 0.25 m^2 to 145m^2, depending on the TCR. Some are unified systems while others can be installed as separate components. This can be useful if it does not have a single space on the ship that is large enough or if access to a single on-board system is difficult.

V. What is the purchase and the operational cost of a BWTS?

A BWTS is a great investment and can cost up to$ 2,000,000, depending on the manufacturer. Concerning the operating costs, depends on the type of system and starts from a few dollars per 1,000 m3 of treated water. Many supply systems report operating costs below $ 20 per 1,000 m^3.

VI. The ship has enough power to perform the operation properly of the system?

Some systems have very high-power requirements - up to 220kWper 1000 m 3 of treated water. It should be checked if needed to operate an additional generator when the system is running or even install an additional generator. Another problem is whether there will be a backup switch on the panel to distribute power to the BWTS separately. If not, you will an alternative must be found.

VII. Will it be able to coexist with existing ship systems?

It is advantageous to integrate its alarms and controls ballast treatment system with those of its pumping system ballast so that both can be monitored and operate from all control panels.

VIII. <u>Consumables, spare parts and the immediate service support?</u>

It is important that the ship's manager be able to maintain the BWTS functional. If it stops working, it will be violated contract and will face fines or ship booking. It is necessary to know that spare parts, consumables and the service are immediately available in all areas of the ship.

4.4. Brief introduction to the AHP multi-criteria analysis method (Analytical Hierarchy Process) - Hierarchy Model

The AHP method was developed by Thomas Saaty (1980) in response to lack of common and easily understood as well as applicable methods in complex decision-making process. Since then, this method has found application in many areas around the world, such as business, governance, social studies, research and development, defense and other areas where decision-making is required, in which choice plays a key role, the priority and forecast. This method is preferred by busy people managers and decision makers due to its simplicity and ease of use. A helping hand is needed to organize the problem and build complexity, measurement and composition of rankings, which makes it suitable for aa variety of applications. The Analytic Hierarchy Process (AHP) develops linearly prosthetic model, but, in its basic form, uses procedures to produce the weights and scores achieved by the alternatives based, respectively, in pairwise comparisons between the criteria and between the options. So, for example, in calculating the weights, they are set to the receiver decisions a series of questions, each of which asks how important it is one specific criterion in relation to another for the decision to be made (Kollia, 2012).

Consistency for pairwise comparisons in AHP is calculated by the consistency ratio (CR- Consistency Ratio), which is the indicator that ultimately determines the consistency of results and thus completes the consistency check. CI is the index of which reveals the deviation of consistency (Kollia, 2012).

5. Conclusions

Shipping is one of the main factors in the intensity of the phenomenon movement of foreign organisms in ecosystems beyond their natural environment. The delay in mobilizing the bodies responsible for treatment of the phenomenon led to its intense deterioration bringing adverse effects on the environment, the economy and human health. Therefore, now the Marine Ballast Convention, which has been much discussed and considered in recent years, entered into force in September 2017.

Shipowners are now obliged to act and proceed with the purchase a reliable system in order for their ships to continue to travel to all parts of the world without restrictions. Nevertheless, the opportunity for a five-year extension to install the system on board passing the five-year inspection (Special Survey), which gives a small margin for postponement in order to formulate a fleet management plan by each shipowner and develop a more reliable advanced market marine ballast treatment system.

The choice of ballast treatment system also requires careful research which must precede its final purchase decision. This paper is a good example of research in its early form as well in addition to the criteria mentioned, others are likely to emerge important factors that should in turn be weighed depending on the company that conducts it. Thus, its ease of application multi-criteria analysis performed above can be adopted by any shipowner, although it will need to consider more factors for the outcome of a more reliable result. But they do not stop bothering and leaving many questions unanswered from the issue of ballast processing. For example, will a substantial solution be given or even to significantly reduce the problem of invasion of alien species in marine ecosystems?

Will the penalties and sanctions that will be imposed on shipowners be able to actually act as an incentive for the ultimate their compliance with the regulations?

Will the manufacturers be able to cope with the increased shipping demand to systems that have entered the market?

Will be there a balance between supply and demand?

Will there be any differentiation in the prices of manufacturers and shipyards as much as the increase of demand?

What will happen if there is a sharp drop in the demand of the BWTS in the near future?

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